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Chapter 3

Values and functions of mires and peatlands

This chapter sets out the types of values that human beings use in making choices between alternative benefits. It sets out the different benefits which are derived from mires and peatlands. A substantial number of experts have contributed material for this chapter.

3.1. What are Values?[1]

Solving conflicts between different uses of mires and peatlands (for example, between economic utilisation and environmental conservation) in a rational way presupposes an understanding of the various values[2] at stake. There are at least three fundamentally different approaches to what values are[3]:

- In the *idealistic* approach, based on ancient Greek philosophy, values are regarded as ideal and objective, independent of the real world. It is assumed that these values are known through a special "intuitus". Followers of this approach are currently rare[4].
- In the *naturalistic* approach, values are regarded as objective properties of an entity[5], independent of the person making the valuation. Things in the real world are considered to have value, just as they have mass or velocity. Several world religions and contemporary environmental philosophers defend this approach[6].
- In the *preference* approach, values are regarded as properties assigned by a valuer, resulting from the preferences of the person making the valuation. "Absolute" values do not exist. Each person is free to value entities as he or she feels about them. Consequent on the many different resulting preferences, a great variety of value-standards exist. None of these value-standards can be considered "better" or "worse" than the others except when other premises make them so. Most experts in value theory (axiology) currently support this preference approach.

Values are generally divided into two categories:

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[1] This chapter has benefited greatly from information provided by, and discussions with, Konrad Ott Martin Gorke, and Anne-Jelle Schilstra.
[2] Different people attribute worth to different qualities. Some may value a mire for its beauty, others for its scientific value, yet others for the peat which can be extracted from it. Others again consider the mire to be of value just because it exists. This last view may seem extreme to pragmatic minds but they must understand that such views do exist.
[3] Prior 1998.
[4] But cf. Taoism and Pirsig 1974.
[5] "Entity" is used in this document as meaning anything which exists whether physically or conceptually (cf. Latin "ens").
[6] Cf. also Table 3/1.

- ***Instrumental values*** are clear means to an end ("instruments"). Instrumental value is equal to **function**[7]: the beneficial effect of an entity on another entity. Instrumental values can be studied systematically by science and are therefore more objective than intrinsic values.
- Entities that are to be respected as such, i.e. independent from everything else, are said to have ***intrinsic moral value*** (or "moral standing").

The existence of intrinsic moral values is logically included in the idea of a mean-end relationship, when a chain of means (instrumental values) is considered to come to an end at something which has value as such (intrinsic value)[8]. Consequently even the preference approach has ultimately to identify objects with "intrinsic value", i.e. that deserve moral respect for their own sake, independent of whether we prefer it or not.[9]

It is therefore a central question to identify which entities have such intrinsic moral value, to which entities we have moral obligations, and for what reasons.

3.2 Positions with respect to intrinsic moral values

Anthropocentrism[10] represents the position that human beings, and only human beings, i.e. individuals of the biological species *Homo sapiens*, have intrinsic value. In its first principle "Human beings are at the centre of concerns for sustainable development", the Rio Declaration (UNCED 1992) takes a clear anthropocentric starting-point. The Universal Declaration on Human Rights[11] attaches intrinsic moral value to all human beings, wherever they are[12]. "Sustainable development" in seeking to meet "the needs of the present without compromising the ability of future generations to meet their own needs"[13] also attaches intrinsic moral value to human beings in the future. From the anthropocentric standpoint, all human responsibilities with regard to non-human beings are based solely on the realisation of human happiness.

To justify the anthropocentric position it is necessary to argue which characteristics of human beings are morally relevant. Non-anthropocentrists argue that any set of morally relevant characteristics which are shared by all human beings will not be possessed by human beings only. They furthermore appeal to consistency: if human beings value a state (such as freedom from pain) in themselves, it is arbitrary and "speciesist" (as in racist, sexist) not to value it also in non-human beings. In this way,

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[7] In this document the term *function* is used to express an action of an entity that positively affects the object of that action (i.e. is useful). Function is the complement of *use*, i.e. the same action (relation, factor) can be seen as a function (from the perspective of the provider) or as a use (from the perspective of the beneficiary).

[8] Outside nihilism, it is illogical to imagine a uni-directional chain of means without any final ends. Mean-end relationships, however, can also be regarded as a network in which the interconnected strands of the web form infinite circular lines without final ends. In such a view a clear distinction between means and ends disappears (see also § 4.10).

[9] Cf. the difference between axiological objectivism and meta-ethical objectivism in Birnbacher 1996.

[10] From the Greek ανθρωποσ, οι ανθρωποι, man, mankind.

[11] UN General Assembly 1948.

[12] Cf. Declaration of the UN Conference on the Human Environment, Stockholm, 16 June 1972: "5. ..of all things in the world, people are the most precious."

[13] World Commission on Environment and Development 1987.

different people attach intrinsic value to different groups of beings with different justifications (see Table 3/1).

Table 3/1: Positions with regard to which beings possess intrinsic value.

Position	Intrinsic value attached to	Presumed relevant characteristics	Groups or persons who support this position (examples)	Remarks
Noo-centrism	all rational beings	Reason, self-consciousness	Immanuel Kant	Excludes the mentally disabled, the severely mentally ill, and babies[14], but covers some animals (great apes[15], dolphins[16])
Patho-centrism	all sentient beings	The capacity to experience pleasure and pain	the Jewish *sa'ar ba'alê hayyîm*[17], Arthur Schopenhauer, Jeremy Bentham, Peter Singer	Pain is presumed to be bad, since every creature seeks to minimise it. Their capacity for pleasure gives sentient beings the right to pursue whatever pleasures are natural to beings of their kind.
Bio-centrism	all living beings	Being alive	Hinduism, Jainism, Buddhism, Muhammad, Albert Schweitzer, Paul Taylor	Sentiency is considered as a means to another end: life. The position appeals to our intuitions that life is "something special"[18].
Eco-centrism	all beings	Being part of the (natural) whole	Buddhism, John Muir	

Although intrinsic value is normally attributed to individual persons, intrinsic moral value can also be attached to groupings or systems, a position called *holism*. Such groupings or systems may include institutions (the "party"), nations (patriotism), the "land", forests, species, ecosystems, and even the whole biosphere. In some of these holistic approaches, individuals are not valued as such and may be sacrificed for the sake of a whole (e.g. species conservation in nature conservation). The Convention on Biological Diversity (UNCED 1992) explicitly acknowledges "the intrinsic value of biological diversity" and consequently attributes intrinsic value to both species (taxa) and ecosystems. (See also § 4.10 below.)

People who cannot draw a boundary between entities with and without moral standing must either attribute intrinsic value to every being (ethical holism)[19], or to no being at all (nihilism).

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[14] Although some of them are "brought back in" again by referring to their potential rationality
[15] Cavalieri & Singer 1993, Parr 2001.
[16] Reis & Marino 2001, Tschudin et al. 2001
[17] "Sympathy for life".
[18] Cf. The World Charter for Nature (UN General Assembly Resolution 37/7 and Annex, 28 October 1982): "Every form of life is unique, warranting respect regardless of its worth to man, and, to accord other organisms such recognition, man must be guided by a moral code of action.", and "General principles. 1. Nature shall be respected and its essential processes shall not be impaired.".
[19] This does not necessarily mean that all beings are considered to have equal value. See also § 4.10 and § 5.7.

Apart from the non-anthropocentrist arguments mentioned above, various other arguments with strong metaphysical premises are used to attribute intrinsic moral value to non-human entities (Table 3/2).[20]

Table 3/2: Other arguments used to attribute intrinsic moral value to non-human entities.

Position	Argument	Examples
Theism	All entities are God, in the image of God, or created to glorify God	Many world and native religions
Nature mysticism	The intuitive feeling of humanity's unity with all nature	Pythagoras, Francis of Assisi, Baruch Spinoza, Herman Hesse, Rosa Luxemburg, Guido Gezelle, John Muir, Henry Thoreau
Holistic rationalism	This world is the "best" of all possible worlds, with a maximum economy of premises and fundamental laws, a maximum diversity of resulting phenomena, and its consistency, order, or "harmony"[21]	Plato, Gottfried Wilhelm Leibniz

Except for nihilists, everyone can agree that intrinsic value exists and that there are morally relevant characteristics, but different groups of people identify different characteristics as morally relevant.

As intrinsic values normally cannot be compromised, the different positions regarding which entities have intrinsic moral value will have an over-riding impact on how conflicts are judged, and may themselves be the main cause of conflict.[22] If some participants in a conflict assume that the integrity of non-human beings is of intrinsic moral value (for example, a sacred cow), they will not accept solutions which other participants, who only look at the instrumental value of these entities (e.g. a cow as a provider of milk and meat), would interpret as fair and well-balanced compromises[23].

[20] Some essentially instrumental positions can come close to attributing intrinsic moral value to non-human beings by:

- assigning them the right not to be unnecessarily violated, in the interests of decreasing the suffering of human beings who suffer when non-human beings are violated (the *sentimental* argument);
- acting as though they also have intrinsic value, to avoid the possibility that some people will treat human beings in the same way as non-human beings are sometimes treated - the psychological *prudential* argument. ("People who delight in the suffering and destruction of inferior creatures, will not … be very compassionate, or benign, to those of their own kind." John Locke, 1693).
- considering them together with human beings, as interdependent and inseparable parts of ecosystems (the *ecological* argument) (Watson 1979).

[21] Similar concepts include the "balance of nature", "nature knows best", and "Gaia" in environmentalism, and the free market ideology in political economy.

[22] See also § 4.9.

[23] Example: Conferring intrinsic moral value on great apes (the "easiest" non-anthropocentric position, because these animals are self-conscious and able to think abstractly) implies that their natural habitats must be taken into moral consideration, e.g. the orang-utan mires in Southeast Asia. This is not because these rare species have an instrumental (e.g. informational) value for human beings, but because the individual apes have intrinsic value, in the same way as human rights have to be respected, not because *Homo sapiens* is a rare species, but because individual human beings have intrinsic value.

In spite of differences on the level of ethical justification, there is some convergence at the level of practical conclusions and political recommendations, as similar conclusions can be reached from different premises[24]. Most people at least agree that all human beings have intrinsic moral value. Enlightened environmentalists and economists will agree that environmental and economic decision-making should take all kinds of values seriously into account.

The following section analyses the instrumental values of mires and peatlands for human beings.

3.3 Types of instrumental values

Instrumental values (functions, services, resources) can be subdivided into ***material*** and ***non-material life support functions*** with various subdivisions (see Table 3/3).

Material life support functions contribute to the maintenance of physical health. They are usually divided into *production*, *carrier*, and *regulation* functions[25]. *Production functions* relate to the capacity to provide (individualisable[26]) resources, ranging from water, food, and raw materials for industrial use to energy resources and genetic materials. *Carrier functions* relate to the capacity to provide space and a suitable subsoil for human habitation, industry, and infrastructure, cultivation (crop growing, animal husbandry, aquaculture), energy conversion, recreation and nature protection. *Regulation functions* relate to the capacity to regulate essential (non-individualisable[27]) ecological processes and life-support systems, contributing to the maintenance of adequate climatic, atmospheric, water, soil, ecological and genetic conditions.

The ***non-material life support functions***[28] cover a large and diverse range of benefits that can be subdivided into two large classes:

> *Proxy functions* include all sensations that are experienced as pleasant, agreeable or beneficial, but whose material advantages are not always immediately obvious. Their real benefits (and genesis) lie deeper[29]. Proxy

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[24] Cf. Norton 1991.
[25] De Groot 1992, Naveh 1994.
[26] Resources which can be divided between individuals.
[27] Resources which are common to all and cannot be divided between individuals.
[28] Jointly called "informational functions" by De Groot 1992. To a large extent, these values include what some philosophers call "eudaimonistic values" (after *e?da?µ???a eudaimonia)* = Greek "good life") that generally enrich life and that are experienced as "good in themselves" (Seel 1991).
[29] Some examples: We enjoy company (social amenity values) because during human evolution co-operation (and therewith its direct individual driving force: the pleasure in social contact) has been more effective for survival and propagation than individualism (Callicott 1988, Diamond 1991, Maynard Smith & Szathmáry 1995). Similarly lying in the sun (recreation values) is enjoyable, as it enables our skin to produce the indispensable vitamin D. We like outdoor experiences because of the resulting stress mitigation (Hartig et al. 1991, Kellert 1993). Aesthetics can be seen as a rapid and integrated ordering and evaluation of a complex set of properties (Berlyne 1971, Kellert 1997). Our predisposition to see beauty in savannah-like landscapes, sunsets, quiet waters, and contained fires goes back to the human past as hunter-gatherers, when these experiences were associated with food and water availability, safety, and security (Ulrich 1993, Heerwagen & Orians 1993, White & Heerwagen 1998). In the same way, human beings are genetically averse to snakes (a fear and fascination we share with African and Asian monkeys and apes), dogs, spiders, enclosed spaces, running water, blood, and heights (Ulrich 1993). We are quick to develop fear and even phobias with very little negative reinforcement (Öhman 1986). Few modern artefacts are as effective - even those most dangerous, such

functions are largely consumed unconsciously. They are shaped and modified by learning, but they do have some genetic, hereditary basis. Behavioural patterns related to these functions may, therefore, long remain the same, even when the conditions have changed and the former benefits have disappeared[30].

Identity functions serve to identify one's position in the world. They are limited to self-conscious beings[31] who are able to think abstractly[32]. The capacity to consume (and create) these kinds of functions must also have had an evolutionary advantage, e.g. by consolidating group behaviour and the development of conscious altruism (solidarity).

The significance of these non-material life support functions for human beings is indicated by the large amounts of money that are spent in such areas as team sports, recreation, arts, religion, history, species conservation, and pure science.

All these functions have a future aspect as *option* or *bequest functions*, which refer to what this generation will leave to future generations. *Transformative / educational functions* lead to a change of preferences or value standards. They only make sense, however, for those who believe that one set of preferences or standards is better than another.

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as guns, knives, automobiles, and electric wires (McNally 1987, Wilson 1993, Kellert 1997). Our erotic preferences instinctively focus - via subtle olfactory sensations (smells)- on people with complementary immune systems (Wedekind et al. 1995, Wedekind & Furi 1997, Cutler 1999). We like salt and fat because in our pre-human savannah past it was beneficial to swallow the full supply of these rare goods whenever they were available (Shepard 1998). Bodily symmetry and beauty seems to indicate health (Cf. Manning et al. 1999, Scheib et al. 1999, Thornill & Grammer 1999). Flowers signal future availability of fruits and honey (being the evolutionary background to giving flowers to sick people and hosts, Heerwagen & Orians 1993), animals scanning the countryside or a startled expression on a person's face alert to dangers (Heerwagen & Orians 1993, Darwin 1998) (signalisation values).

[30] An unlimited consumption of sun and fat for example may lead to skin cancer and cardiac diseases.

[31] Symbolisation values might be considered the "self-conscious" offshoots of indicator values; spiritual, existence, and historical values as the offshoots of social and amenity values; cognition values as those of aesthetic values.

[32] In contrast to proxy values, identity values are not only "consumed" but also to some extent "produced" by human beings themselves ("identi-*fication*") . Our "world-views" not only rest on "objective" observations, but also on subjective interpretations and projections. This applies for example for history (cf. Walsh 1967, Harmsen 1968, Marwick 1989), science (cf. Popper 1959, Kuhn 1972, Bartels 1987), and spirituality and religion (Midgley 1996, Wilson 1998, cf. Xenophanes 6th century BC in Fairbanks 1898: "But mortals suppose that the gods are born (as they themselves are), and that they wear man's clothing and have human voice and body. But if cattle or lions had hands, so as to paint with their hands and produce works of art as men do, they would paint their gods and give them bodies in form like their own - horses like horses, cattle like cattle.").

Table 3/3: Types of instrumental values

<table>
<tr><th colspan="4"></th><th>Examples</th></tr>
<tr><td rowspan="12">Present day aspects</td><td rowspan="3">Material life support functions</td><td colspan="2">1. Production functions (see § 3.4.1)</td><td>Providing water, food, raw materials, energy, labour</td></tr>
<tr><td colspan="2">2. Carrier functions (see § 3.4.2)</td><td>Providing space and substrate for habitation, cultivation, energy generation, conservation, recreation</td></tr>
<tr><td colspan="2">3. Regulation functions (see § 3.4.3)</td><td>Regulating climatic, water, soil, ecological, and genetic conditions</td></tr>
<tr><td rowspan="9">Non-material life support functions (§. 3.4.4)

(= infor-mational functions)</td><td rowspan="4">4. Proxy functions</td><td>4a. social amenity functions</td><td>Providing company, friendship, solidarity, erotic contact, cosiness, respect, home, territory, employment</td></tr>
<tr><td>4b. recreation functions</td><td>Providing opportunities for recreation, recuperation, stress mitigation</td></tr>
<tr><td>4c. aesthetic functions</td><td>Providing aesthetic experience (beauty, arts, taste)</td></tr>
<tr><td>4d. signalisation functions</td><td>Providing signals (indicator organisms, status, monetary price, taste)</td></tr>
<tr><td rowspan="5">5. Identity functions</td><td>5a. symbolisation functions</td><td>Providing embodiments of other functions (mascots, status symbols, money)</td></tr>
<tr><td>5b. spirituality functions</td><td>Providing reflection and spiritual enrichment (religion, spirituality)</td></tr>
<tr><td>5c. history functions</td><td>Providing notions of cultural continuity (history, heritage, descent, ancestors)</td></tr>
<tr><td>5d. existence functions</td><td>Providing notions of ecological and evolutionary connectedness</td></tr>
<tr><td>5e. cognition functions</td><td>Providing opportunities for cognitive development (satisfaction of curiosity, science)</td></tr>
<tr><td colspan="2" rowspan="2">Future aspects (see § 3.4.5)</td><td colspan="2">6. transformation (= educational) functions</td><td>Providing a change of preferences, character building</td></tr>
<tr><td colspan="2">7. option (= bequest) functions</td><td>Providing insurance, heritage</td></tr>
</table>

Restricted to self-conscious beings   not restricted to self-conscious beings

3.4 Functions of mires and peatlands for human beings

This section outlines the beneficial functions of peatlands, and their significance in global, regional and local terms. Table 3/4 summarises these functions, and is followed by explanatory text on each function.

Table 3/4: Overview of functions of mires and peatlands for human beings

3.4.1 Production functions: (a) Peat extracted and used ex situ as/for (aa) Humus and organic fertiliser in agriculture (ab) Substrate in horticulture (ac) Energy generation (ad) Raw material for chemistry (ae) Bedding material (af) Filter and absorbent material

(ag) Peat textiles
(ah) Building and insulation material
(ai) Balneology, therapy, medicine, and body care
(aj) Flavour enhancer
(b) Drinking water
(c) Wild plants growing on mires and peatlands for/as
(ca) Food
(cb) Raw material for industrial products
(cc) Medicine
(d) Wild animals for food, fur, and medicine
(e) Peat substrate in situ for
(ea) Agriculture and horticulture
(eb) Forestry

3.4.2 Carrier functions: space for
(f) Water reservoirs for hydro-electricity, irrigation, drinking and cooling water, and recreation
(g) Fish ponds
(h) Urban, industrial, and infrastructure development
(i) Waste deposits / landfill
(j) Military exercises and defence
(k) Prisons
(l) Transport and herding

3.4.3 Regulation functions:
(m) Regulation of global climate
(n) Regulation of regional and local climates
(o) Regulation of catchment hydrology
(p) Regulation of catchment hydrochemistry
(q) Regulation of soil conditions

3.4.4 Informational functions:
(r) Social, amenity and history functions
(s) Recreation and aesthetic functions
(t) Symbolisation, spirituality, and existence functions
(u) Signalisation and cognition functions

3.4.5 Transformation and option functions

3.4.1 Production functions

(a) Overview of peat extraction[33]

Peat is extracted from peatlands and used principally in horticulture, agriculture, domestic heating and energy generation. Peat is either cut from the peatlands as sods, or macerated and formed into sods, or milled on the surface to form crumb. Peat extraction includes the drying of wet peat and the collection, transport and storage of the dried product. The drying process is in two phases:

- a substantial proportion of the water content is taken away by drainage;
- moisture content is then further reduced by solar and wind drying on the surface of a production field.

[33] Based on information from Timo Nyronen.

Because of this dependence on meteorological conditions, annual peat production volumes in an enterprise or country may fluctuate considerably.

A mire or peatland is suitable for industrial peat extraction if

- the peat is of sufficient depth.
- its area is sufficiently large and of appropriate shape,
- the quality of peat is adequate for the intended purpose,
- access to the consumer can be achieved at a reasonable price.

Accurate information on the extent of peat extraction is not available. In particular, little is known about the volumes of private, non-industrial peat extraction that remains important for local energy provision in countries like Ireland, some central Asiatic republics[34], and China[35]. The latest available information on industrial peat extraction volumes is contained in the Tables in the sections dealing with peat in horticulture (ab) and for energy (ac).

(aa) Peat as humus and organic fertiliser in agriculture[36]

Peat has been used as an organic raw material in the production of organic fertilisers and combined organic-mineral fertilisers and in the improvement of degraded soils by adding humus. Practice in this area differs greatly between different countries.

The most important value of organic or organo-mineral fertilisers produced with peat is in their organic matter containing biologically active substances. Organic substances enrich the soil with trace elements, improve the physical properties of the soil, its pH level, and its productivity.

Peat was used as an organic fertiliser in great quantities in agriculture in the years 1950-1980 (Fig. 3/1). During this period different mixtures, including composted mixtures, were prepared, especially in the Soviet Union. Excavated peat, both raw and dried, was mixed with sandy or loamy soils. This improved the physical properties of the soils but did not change plant nutrition. In the Soviet Union, Ireland, France and Poland considerable research was carried out into the liquid ammonia treatment of peat (15-35 kg NH_4OH/Mg peat), used in agriculture in 10-40 Mg/ha doses. These experiments did not give positive results. Mixtures of peat and different mineral fertilisers had the nutrient value of the fertilisers only. Composts produced using peat with stable manure, sewage sludge, faecal substances, liquid manure and different organic municipal and industrial wastes in 1:1-2:1 ratios were expensive to produce and were not effective.

The results obtained from the use of peat preparations have not shown any significant correlation between inputs and either the chemical properties of plants or their yield. Since the political changes in the former Soviet Union, the volume of peat extracted for agricultural purposes has substantially diminished (cf. Fig. 3/1 and Table 3/5).

It is possible that in the future peat could have an economically effective role in the remediation of degraded soils and as topsoil replacement in the regeneration of areas used in open-cast mining.

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[34] Joosten 2001.
[35] Xuehui & Yan 1994.
[36] Based on information from Piotr Ilnicki. Cf. also Lishtvan 1996.

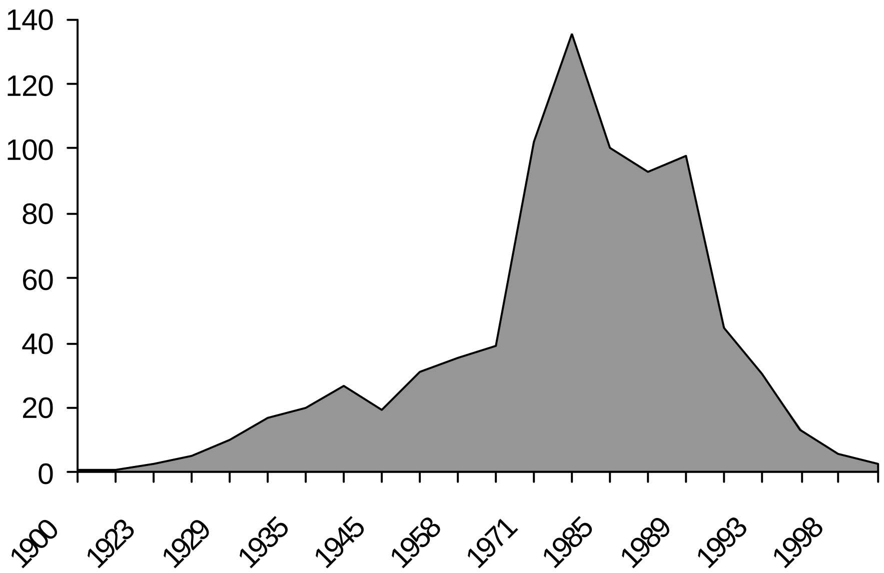

Fig. 3/1: Annually extracted volume of peat in the Russian Federation in million tonnes at standardised moisture content[37].

(ab) Peat as a substrate in horticulture[38]

The most common current use of peat is for horticulture (cf. Tables 3/5 and 3/6). The production of greenhouse and container crops involves the integrated management of water, fertilisers, pesticides, and growing media. Of these probably the most important is the type of growing media used. Due to the limited volume of a pot, container or tray module, growing media must provide the appropriate physical, chemical and biological conditions for plant growth. In countries with a modern horticultural industry peat has emerged as the foremost constituent of growing media. The production and processing of peat-based growing media has become a precondition for horticulture. The 'John Innes Composts', the 'Einheitserde' and the 'Torfkultursubstrat' have been milestones in the development of peat-based growing media.

[37] From Sirin & Minaeva 2001. This Figure includes all extracted peat but is given here to illustrate the dramatic fall in extraction which is due in part to the reduction in the use of peat in agriculture.
[38] Based on information from Gerald Schmilewski. Cf. also Schmilewski 1996.

Table 3/5: Production of peat used in horticulture and agriculture (in millions of cubic metres)[39]

Country	**1990**	**1997**	**1998**	**1999**
Belarus	10.9	0.3	0.4	0.8
Russia	24.0	2.5	0.8	1.1
Ukraine	9.8	0.1	0.2	0.3
Czech Rep	0.3	0.4	0.1	0.2
Estonia	0.0	3.5	1.0	3.5
Finland	1.5	1.6	0.3	2.4
Germany	6.6	9.0	9.6	9.5
Hungary	0.1		0.1	0.2
Ireland	2.0	2.8	3.2	3.2
Latvia	13.2		0.7	0.0
Lithuania	2.0		0.4	0.8
Poland	0.3	0.7	0.7	0.8
Sweden	0.0	0.6	0.6	1.4
Norway		0.1		0.1
Denmark		0.5		
UK	1.4	2.5	1.9	2.5
USA	1.2	2.2	1.4	1.4
Canada	6.6	7.0	8.8	10.3
N Zealand	0.0		0.1	
TOTAL	79.9	33.8	30.3	38.5

The use of standardised peat-based growing media in horticultural plant production developed for reasons of economics and because of technological advances. Industrially processed peat-based growing media have widely replaced growers' self-made mixes. Continuous research and increasing knowledge of the properties of the constituents of growing media show that growers run considerable risks if they apply the wrong materials or the wrong quantities of materials. The major advantages of *Sphagnum* peat as a constituent of growing media include:

- its cellular structure ensures good water holding ability;
- its low pH and nutrient status allow easy adjustment by the addition of crop-specific fertilisation and liming;
- it is free from pathogens, pests and weeds;
- it is easy to handle, process, grade and blend;
- peat products are available on a world-wide basis;
- 'alternative' growing media work best when they contain an element of peat.

Peat substrates are used particularly in glasshouse horticulture for the cultivation of young plants, pot plants and for the growing of crops such as bedding plants and vegetable plants in containers[40]. It is also sold to amateur gardeners as a soil conditioner. In Europe, approximately 95 % of all growing media for the professional

[39] Source: IPS 2000 Survey. These figures may not be consistent as different moisture contents may be used. However, the purpose of the table is to indicate trends.
[40] Van Schie 1999.

and amateur markets are peat-based. In countries such as Finland, Germany, Ireland, Sweden and the U.K. domestic peat resources provide horticultural enterprises with peat-based media for growing crops. Countries such as Belgium, France, Italy, the Netherlands and Spain depend on imports of peat and peat-based growing media to support and sustain their horticultural business. The export of peat from the Baltic States to Western Europe is increasing. In North America the same is true of exports from Canada to the U.S.A.[41]

Peat is used as a component of mushroom casing for commercial production of edible mushrooms (*Agaricus bisporus*) and oyster mushrooms (*Pleurotus ostreatus*), and as a carrying medium for rhizobial inoculants for vegetable production (e.g. soybeans)[42].

Although peat has maintained its position as the leading material for growing media, and is the preferred product among amateur gardeners, 'alternative' materials have emerged as substitutes for peat where feasible and safe for use (Table 3/6). These materials include coir[43], wood fibre, composted bark and composted biogenic waste. Environmental awareness, increasing knowledge of the interactions of media properties and product diversification have helped introduce these alternative materials. The peat industry is now participating in research into 'alternative' materials and is introducing products containing these materials. In spite of these developments, there is not at present any alternative material available in large enough quantities and equally risk-free which could replace peat in horticultural crop production.

Table 3/6: Estimated amounts of materials used for the production of growing media in Germany and the Netherlands for the professional and hobby market in 1999[44]

MATERIAL	GERMANY		NETHERLANDS	
	m^3	%	m^3	%
Black peat	6,000,000	63	1,500,000	39
White peat	3,000,000	32	1,600,000	42
Wood fibres	190,000	2	5,000	<1
Clay (fresh and dried)	170,000	2	/	/
Composted biogenic waste	90,000	1	/	/
Composted bark / Bark	30,000	<1	40,000	1
Mineral wool	20,000	<1	500,000	13
Perlite	9,000	<1	50,000	1
Sand	8,000	<1	/	/
Coir (fibres and dust)	5,000	<1	100,000	3
Rice hulls	3,000	<1	10,000	<1
Pumice	400	<1	20,000	<1
Expanded clay	400	<1	20,000	<1
Others (lava, vermiculite, Synthetic-organic material, etc.)	7,000	<1	5,000	<1
TOTAL	**9,522,800**	**100**	**3,850,000**	**100**

[41] Joosten 1995.
[42] Turner 1993.
[43] Coir fibre dust is a by-product of the coconut processing industry.
[44] Van Schie 1999.

(ac) Peat for energy generation[45]

Within Europe, peat is an important local or regional energy source in Finland, Ireland and Sweden. It also continues to be important in the Baltic States[46] and in Belarus and Russia (Table 3/7). In Asia, peat is also used for energy purposes in parts of China[47] and Indonesia, but reliable volume estimates are not available. A small amount of sod peat is produced for energy purposes in the mountain regions of Burundi in Africa.

The global use of peat for energy is estimated to be 5 to 6 million tonnes of oil equivalent (Mtoe) (Table 3/8).

Table 3/7: Production of peat for energy (in million tonnes)[48]

Country	**1990**	**1997**	**1998**	**1999**
Belarus	3.4	2.7	2.0	3.1
Russia	6.0	2.9	1.9	3.7
Ukraine	1.3	0.6	0.6	0.5
Estonia	0.0	0.2	0.2	0.6
Finland	5.8	10.1	1.5	7.5
Ireland	7.5	4.0	4.3	4.7
Latvia	0.3		0.1	
Lithuania	0.8	0.1	0.2	0.4
Sweden	0.0	1.4	0.2	1.1
TOTAL	25.1	22.0	11.0	21.6

In Finland, peat is used mainly in co-generation (combined heat and power, CHP) and in heating facilities. It is an important fuel for district heating in regions where other sources of energy are not readily available. The total installed capacity is over 750 MW_e and 1500 MW_{th}, and includes 60 district heating plants, 34 CHP facilities, 30 industrial plants and one condensing power plant. In Ireland peat is used for power generation in condensing power plants, and also as a fuel for household space heating. The older generation of pulverised fuel power plants is being phased out and will be replaced by three fluidised-bed-based plants with a combined capacity of 370 MW_e. In Sweden peat is used in 35 heating plants, the largest of which is located in Uppsala. Small-scale space heating applications and the manufacture of peat briquettes for use in private houses are typical in the Baltic countries.

[45] Based on information from Charles Shier. Cf. also Asplund 1996.
[46] Leinonen et al. 1997.
[47] Cf. Changlin et al. 1994, Xuehui & Yan 1994.
[48] Source: IPS 2000. The figures are not strictly consistent, as different countries estimate tonnes in relation to different moisture contents. In addition, the table combines milled and sod peat at different moisture contents. However, the purpose of the table is to indicate trends. It is clear that production of peat for energy has substantially reduced in the countries of the former Soviet Union and in Ireland.

Table 3/8 Consumption of peat for energy (in million tonnes of oil equivalent per year)[49]

Country	Energy Peat Use (Mtoe a^{-1})
Finland	1.90
Ireland	1.20
Sweden	0.30
Belarus	0.55
Russian Federation[50]	0.55
Ukraine	0.12
Estonia	0.35
Latvia	0.11
Lithuania	0.03

Peat as a source of energy is most beneficial in areas where there is an absence of other fuels, and where energy supply entails transportation of conventional fuels over long distances. As an energy source peat closely resembles wood, and the two are often used together in co-fired applications. Both the calorific value and the carbon content of peat are lower than those found in brown coal (lignite) or in bituminous coal, but the proportion of volatiles in peat is higher. The sulphur content varies with location, but is typically less than 0.3% on a dry mass basis. In the past, grate firing (sod peat) and pulverised firing (milled peat) have been the dominant technologies; but from the 1980s onwards larger scale applications have been based on fluidised-bed combustion which has resulted in higher efficiencies, lower emissions and multi-fuel capabilities.

Looking to the future, peat is expected to remain an important source of energy in rural and isolated regions of countries with abundant peat reserves. On a global scale, it is not anticipated that the use of peat for energy will increase greatly, although there is scope to substitute peat for certain imported fuels in some of the Baltic States. Given its high volatile content peat is suitable for gasification, and the maturation of integrated gasification combined cycle (IGCC) technology may lead to even more efficient peat use for energy in the future.

(ad) Peat as a raw material for chemistry[51]

Peat organic matter is a valuable raw material for chemistry. Chemical peat-processing is carried out by hydrolysis, pyrolysis, extraction and chemical

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[49] For 1999 or earlier years, depending on the availability of information. Based on the work of the Energy Peat Working Group of Commission II of the I.P.S.
[50] First National Communication to the UNFCCC 1995. Interagency Commission of the Russian Federation on Climate Change Problems, Moscow.
[51] Based on information from Nikolai Bambalov. For an extensive overview cf. also Fuchsman 1980, Lishtvan 1996.

modification. The chemical processing of peat to obtain a specific type of organic compound also produces new substances as a side effect.

Peat wax extraction is one of the indispensable stages in extraction techniques. The wide spectrum of valuable properties of wet peat wax has made it possible to find different applications (such as moulds for precision casting in machine-building, protective and preservative materials for engineering).

Peat dye imparts a uniform nut-brown colour to wood, enhances its texture and, compared to other dyes, raises considerably less nap[52], does not diffuse into finishing materials, is not toxic and is characterised by high light durability. It is easy to mix with synthetic dyes and thus to obtain a range of different hues.

Specific examples of the use of peat in chemical processing include:

1. Water soluble humic preparations have been found to be effective in the purification of metallic surfaces from radioactive substances. They were used successfully in the Chernobyl zone in 1986-1987 for the purification of technological equipment. It is considered that they may have potential in the purification of technological equipment in active nuclear power stations.
2. Humic preparations which are soluble in acids have been used for the extraction of valuable metals from raw materials, especially in underground extraction.
3. Activated carbon from peat is effective in a number of applications including the purification of soil and water from organic contaminants, for example from pesticides[53].
4. Peat has been found to be an inhibitor of corrosion. Special preparations for the transformation of rust into metal have been widely used in Belarus, for example to remove rust from automobiles.

The total amount of peat used in the chemical industry is not great. For example, in Belarus the amount used is not more than 10,000 tonnes per year. Globally approximately 138,000 tonnes of black peat per year are used to produce some 15,000 tonnes of activated carbon[54].

(ae) Peat as bedding material[55]

Slightly humified sphagnum peat ("white peat", "peat moss") was used as a litter in stables in enormous amounts from ca. 1885 until 1919. This use was the basis for the explosive development of the peat moss industry in countries such as Germany, Sweden and the Netherlands.

The main users were armies, transport companies, railways, mining companies and industrial enterprises where horses were employed. For example, the Compagnie Générale d'Omnibus in Paris had 13,500 horses. If the amount of peat used per horse

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[52] A soft surface on fabric or leather.
[53] Zagwijn & Harsveldt 1973.
[54] Gerding 1998. The peak production was in 1975 when 230,000 tonnes of peat were used to produce 25,000 tonnes of activated carbon.
[55] Based on information from Henk van de Griendt.

per day is estimated at 4 to 5 kilos, this one customer needed about 22,000 tonnes per year.

Dry peat moss can absorb about ten times its own weight in liquids, reduces unpleasant smells and has a favourable effect on the health of the animals. These were major advantages compared to straw. Another advantage was the after-use of the peat as manure for local vegetable-growers.

Peat moss was later used for the same purpose for poultry and cats. In the Netherlands and Germany it was even recommended for babies, although the cot had to be adjusted to use this uncommon material.

The use of peat as litter continues to-day[56].

(af) Peat as a filter and absorbent material[57]

Peat functions as a filter and absorbent material both in situ (see § 3.4.2 (i)) and ex situ. The pollution treatment capabilities of peat materials include:

1. Physical filtration
2. Chemical adsorption/absorption
3. Biological transformations.

Because of the high cation exchange capacity, porosity, surface area and absorption ability of peat, all of the above treatment characteristics occur simultaneously within a peat material whether used for water/wastewater or gaseous treatment.

Firstly, the peat filters out suspended solids and microbiological contaminants. Secondly, chemical components are adsorbed or retained within the peat. Finally biological inactivation occurs as a result of the proliferation of a microbial population indigenous to the peat.

Numerous environmental uses have been identified for peat materials (and by-products)[58] which are currently being scientifically validated. These include the use of peat as a microbial carrier, the use of younger *Sphagnum* peat as an oil spill absorbent, and, finally, the removal of heavy metals from trade effluents.

These pollution treatment qualities of peat have been successfully commercialised by a number of peat extraction companies.

(ag) Peat textiles[59]

Under the long-term influence of humus and humin substances, the basal sheaths of cottongrass (*Eriophorum vaginatum*) in peat undergo a change into brown, 5-20 cm long fibres, which are soft enough to be used for textiles. These fibres are warmer

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[56] O'Gorman 2002.
[57] Based on information from Eugene Bolton. Cf. also Mutka 1996.
[58] Viraraghaven 1991, Viraraghaven & Rana 1991. See also many other contributions in Overend & Jeglum 1991.
[59] Based on information from Marjatta Pirtola. Cf. also Pirtola 1996.

than wool because of their cavity-like, air-filled structure, which makes them also very light. Peat textiles are thus especially suitable for those who need extra warmth, such as infants, the elderly and rheumatism sufferers. The fibres easily absorb and release liquids and have the ability to absorb the secretions of the skin including perspiration and salts, in addition to absorbing smells. They do not acquire an electric charge and burn poorly, like wool.

Early experiments in the 1890s to produce textiles from these fibres failed because the products were too expensive. During the First World War interest in peat textiles was rekindled for a short while, especially in Germany, where they were used for horse blankets, soldiers' clothing and even bandages in hospitals because of the antiseptic and therapeutic properties of peat. After the war this interest ceased.

Since the late l960s peat textiles have been produced in southern Sweden, carded on a 50/50 basis of cottongrass fibres with wool and used for bedclothes or spun into yarn for knitwear or fabrics. Since 1992 some production has also taken place in Finland where small firms produce felt clothes such as hats, coats and loose soles as well as knitwear and woven textiles out of cottongrass fibres and wool. Fibres are bought from Finnish peat mills where they are screened out of the peat as being unsuitable for horticultural use.

Peat has also been used to produce paper. It is thought that the experiments in using peat for paper accelerated the discovery of its potential for peat fibre and as an insulating material[60].

(ah) Peat as building and insulation material[61]

Peat was used in many countries as a building material. In Ireland, the Netherlands and Germany, the very poor also built their homes from sods of turf[62]. Peat has been used in Germany as an insulation material in wooden cottages: in this usage peat is packed in large sheet-form bags and placed along the wall of the building. Sod peat was (and still is) used in constructing the banks of Irish canals. In some parts of Finland sod peat is used as a foundation material on the roads in place of gravel. In Norway compressed peat bales have been used as foundation for rail tracks in areas prone to soil movement from frost[63]. In Russia and Belarus peat has been widely used as an insulation material in the form of dry pressed sheets, for example in industrial refrigerators, or as peat boards in poultry stables[64]. It is understood that sod peat has been used as insulation material for missile silos in the former Soviet Union.

(ai) Peat in balneology, therapy, medicine and body care[65]

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[60] Kelleher [date to be inserted]
[61] Material compiled by Raimo Sopo and Donal Clarke. Cf. also Fenton 1987.
[62] Feehan & O'Donovan, 1996, Martens 1974.
[63] Turner 1993.
[64] Moore & Bellamy 1974.
[65] Based on information from Gerd Lüttig and Nikolai Bambalov. Cf. also Korhonen & Lüttig 1996, Lishtvan 1996, Lüttig 2000.

In many countries there is a long tradition of using mud for human and veterinary therapeutic purposes. By chance peat was substituted for mud, and from 1802 (first in Eilsen Spa, near Hanover, Germany and later in Nennodorf and Marienbad - Mariánske Lázné in the Czech Republic) this balneological speciality spread across Central Europe and later to some other European countries including Estonia, the Ukraine and Poland.

The material used is mainly strongly humified sphagnum peat ("black peat"), but younger sphagnum peats as well as lacustrine muds ("Mudde, Gyttja, Sapropel") are in use in some places.

The fields in which peat is indicated for human medical treatment are:

- gynaecology (illnesses of the female urogenital system)
- illnesses of the locomotion system (the so-called rheumatic field)
- dermatology
- interior illnesses
- ophthalmology

The application is done by peat pulp baths (42-45^{o} C.), poultices, peat kinesitherapy, and peat kneading. In some cases cryo-therapeutic use is to be recommended. Peat preparations are also used.

The effect of peat therapy arises from thermophysical and biochemical mechanisms. Peat baths are, by their heat radiation, able to cause overheating effects, favourable to changes in the digestive system; they act as a relaxing medium because of their buoyancy forces, which are favourable to the spinal system. As peat contains biologically active substances, of which humic acids are the most important, peat influences the immune system positively, and is effective against bacteria, viruses and inflammation.

Peat chemical processing has resulted in the development of a number of preparations with growth-stimulating, fungicidal and bactericidal properties. Hydrolysates of peat contain a wide spectrum of amino, carbonic and uronic acids, humic substances and other compounds which can activate or inhibit various biological processes. Peat oxidate has been found to be helpful in the treatment of skin diseases. Compounds combining volatiles with water steam have been used in the treatment of eye diseases.

Peat has also been successful in veterinary medicine. In Central and Eastern Europe (Belarus, Poland, Russia, Ukraine) peat preparations were used in the large-scale rearing of cattle, pigs and poultry as growth promoters and as medicine, immunological stabiliser, nutrient yeast, carbohydrate fodder additives, and absorbents of harmful substances.

Peat preparations have also been used in plant production as growth promoting, fungicidal and bactericidal substances. Peat oxidates have been used as a treatment for microbiological diseases of agricultural crops, for example with phytophtorose of potato and tomato.

Because of its absorptive properties, peat is also used in nappies (diapers) and in feminine hygiene products[66].

(aj) Peat as a flavour enhancer[67]

The term whisky is derived from the Gaelic *uisge-beatha* meaning water of life, a spirit produced by the distillation of beer. Two distinct types of whisky, malt and grain, are produced in Scotland. Single malts are distilled in simple copper pot-stills from a mash derived entirely from malted barley. Grain whisky is produced by continuous distillation in a patent or 'Coffey' still and the raw material contains a proportion of non-malted cereal.

The first stage in malting is to steep screened barley in water for two to three days until the grain becomes soft and swollen. It is then spread on special floors to germinate under controlled conditions for about two weeks. The "green malt" is then dried slowly over a smouldering peat fire. The more prolonged the kilning and the more intensive the peat "reek", the richer the peaty flavour of the product.

Kilning and curing are arts passed down from generation to generation and each distillery or malting maintains strict security over the processes involved. Thus, little information is available on the importance of peat quality and quantity in the malting process. In general, highly decomposed peat, known locally as blue or black peat, seems to be preferred.

Despite the disadvantages associated with small-scale production units, some distilleries and individual maltings still select, cut and harvest their own peat supplies annually. More recently the use of air-dried peat sods to fuel open fires in the traditional malting process is being superseded by the combustion of peat pellets in special burners resulting in better overall control and efficiency and a significant reduction in the quantity of peat required.

In China the flavour from burning local peat is used for making "weisky wine"[68].

(b) Drinking water[69]

The role of peatlands in the provision of drinking water is important both in areas where catchment areas are largely covered by peatlands, and in drier regions where peatlands indicate a rare but steady availability of water.

Significant areas of the British uplands are secured by the various Water Authorities, that supply water to distant urban centres, e.g. Welsh water to Liverpool and Birmingham, and Lake District water to Manchester. Haworth Moor of "Wuthering Height" fame, for example, was owned by North West Water[70]. In case of Yorkshire Water, some 45% of the water for public supply is obtained from reservoirs draining

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[66] Turner 1993.
[67] Based on information from Allan Robertson. See also Robertson 1975.
[68] Xuehui & Yan 1994.
[69] Cf. Safford & Maltby 1998. Cf. UNESCO 1978.
[70] http://www.gn.apc.org/eco/resguide/2_20.html

peatland areas. The water company owns a large area of the catchment and manages it for water quality improvement by preventing pollution, limiting erosion, reinstalling high water tables, and restoring moorland species such as *Sphagnum*[71]. Often this use is associated with the construction of water reservoirs (see also § 3.4.2 (f)).

Mires may fulfil an essential role as source areas for rivers; especially in maintaining low flows during dry periods. New techniques using long horizontal rather than vertical wells show that they can provide significant amounts of groundwater without compromising ecosystem quality.

Where or when existing water resources are rare, mires and peatlands can be important as sources of water[72], for examples in KwaZulu-Natal[73] and in Sarawak[74].

The water quality in peatlands is usually very good; the frequently abundant humic acids responsible for deep brown colouring can easily be removed[75].

(ca) Wild plants growing on mires and peatlands for food[76]

One of the oldest and most widespread utilisation of wild plants in peatlands is their use as straw and fodder for domestic animals. In Europe, Asia, and North America, fen peatlands have been intensively cut for hay in the past. In the last decades this type of use has decreased, but it is still important locally in Central Europe. Peatlands are also important as wild pasture for domestic animals in many areas of the world, such as for cattle on Argentinian pampas and Lesotho and Kyrgistan mountain peatlands[77], for sheep and red deer in the Scottish blanket peatlands, and for water buffalo in Georgia and Kalimantan[78].

A second important use - especially in the temperate and boreal zones of Eurasia - is the collection of a wide variety of wild edible berries and mushrooms that are preserved and dried and provide substantial food and vitamins in the winter period. With 100 mg in every 100 g of berries, cloudberry (*Rubus chamaemorus*) has for centuries been an important source of vitamin C for the inhabitants of Fennoscandia and helped to keep them free of scurvy. Other edible berries common on mires and peatlands include cranberries (*Oxycoccus*), a whole range of blueberry (*Vaccinium*) species, crowberries (*Empetrum*), raspberries and brambles (*Rubus*) and currants (*Ribes*). In good berry years, about 12 million kilogrammes of berries are picked from mires in Finland (7.8% of the biological yield). It has been estimated that in a normal year the monetary value of wild berries collected from Finnish peatlands is US$ 13.4 million.

Before the emergence of rice, wild sago (*Metroxylon sagu*) was the main source of sustenance for the inhabitants of the Malay archipelago region. Desiccated products

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[71] Butcher et al. 1995.
[72] Cf. Saeijs 1997.
[73] Grundling et al. 1998.
[74] Ong & Mailvaganam 1992, Lee & Chai 1996, Page & Rieley 1998.
[75] Personal communication from David Price, Institute of Hydrology, Scotland, 2000.
[76] Cf. Salo 1996.
[77] Joosten 2001.
[78] Dent 1986.

made from sago starch can be stored for exceptionally long periods and enabled the early inhabitants of the Malay archipelago to travel far and to colonise many islands[79].

Wild rice (*Zizania aquatica*) was an important staple crop gathered by native Americans. Currently most production takes place in regular agriculture (see § (ea) below).

In Europe the peatland species *Menyanthes trifoliata*, *Acorus calamus*, and *Hierochloe odorata* are used for flavouring drinks[80]

(cb) Wild plants as raw material for non-food products[81]

Peatland plants are harvested for human and animal food, and also as raw material for industrial products and energy generation[82] (Table 3/9). For many centuries *Sphagnum* moss has been used as a building and insulation material to fill the chinks between logs and planks in log-cabins and in boats. The Lapps in northern Fennoscandia used peatmoss in children's cots.[83]

Commercial harvesting of live *Sphagnum* moss from peatlands for horticulture, including the cultivation of orchids and bromelias, currently takes place in North America, Australia, and Chile[84].

Harvesting and use of reeds from peatlands takes place all over the world. The use of *Phragmites*[85], *Cladium*, and *Cyperus papyrus*[86] is important for construction purposes, e.g. for thatching and matting, and for making paper.

Table 3/9: Examples of biomass utilisation from undrained peatlands (demand for quality: + = high. 0 = medium, - = low[87])

Utilisation		Vegetation	Harvest	Quality
In agriculture	Mowing, fodder	Wet meadows, reeds	Early summer	+
	Grazing	Wet meadows, reeds	Whole year	+
	Litter	*Carex*-meadows, reeds	Summer	-
	Compost	Wet meadows, reeds	Late summer	-
	Pellets	Wet meadows, reeds	Early summer	+
Industrial	Roofing material	Reeds	Winter	+
	Form-bodies	Wet meadows, reeds	Autumn/winter	0

79 http://www.econ.upm.edu.my/~peta/sago/sago.html; Stanton & Flach 1980.
80 Personal communication from Lenka Papackova.
81 Based on information from Wendelin Wichtmann. Cf. also Wichtmann 2000.
82 Björk & Granéli, 1978, Brenndörfer et al., 1994, Schmitz-Schlang, 1995, Schäffer et al. 1996, Kaltschmidt & Reinhardt, 1997; Michel-Kim, 1998, Schäfer et al., 2000.
83 Sjörs 1993.
84 Elling & Knighton 1984, Whinam & Buxton 1997, Whinam et al. 2000, www.losvolcanos.com
85 Rodewald-Rodescu et al. 1965, Rodewald-Rodescu 1974, Thesiger, 1964, 1979, Hawke & José 1996, Schäfer & Wichtmann 1998, Weijs 1990, Yuqin et al. 1994, Scott 1995.
86 Denny 1993
87 Wichtmann et al. 2000.

Utilisation (continued)		Vegetation	Harvest	Quality
	Paper (cellulose)	*Phalaris*-reeds, *Phragmites* reeds	Winter	0
	Basket-wares	Willow (*Salix*)	Autumn	+
	Furniture/timber	Alder (*Alnus*) swamps	Frost	+
	Chemicals	Reeds	Early summer	+
Energy	Pyrolysis	Alder swamps, willow	Winter	0
	Direct firing	Alder swamps, reeds	Autumn/winter	-
	Fermentation	Wet meadows, reeds	Early summer	0

Biomass with commercial potential can be harvested from both undrained and re-wetted peatlands, which makes possible an economic exploitation combined with the conservation of many natural mire functions[88]. *Phragmites australis* reeds, for example, represent the natural vegetation of eutrophic flood and immersion mires[89]. In such mires thick layers of reed peat can be found. Similar *Phragmites* reeds with peat-forming potential may develop spontaneously or can be established artificially after rewetting of degraded peatlands.

In a number of countries the demand for reed as a roofing material and for the production of mats cannot be satisfied by native reed harvests and imports[90] are needed to meet current demand. In addition to these traditional products, new products made from peatland biomass[91] are becoming economically interesting, e.g. form bodies as packaging material[92] and vegetation- and plaster-porter mats[93], insulation material and construction sheets[94], pulp for paper production[95], the bio-refinement of plant saps for the production of biotechnological raw materials[96].

(cc) Plants for medicine[97]

Mire plants are widely used for medicinal purposes in all parts of the world, principally in areas with large numbers of mires[98]. The number of mire/wetland plants used for medicine on a world-wide scale can be conservatively estimated at some thousand species. The majority is used by local and indigenous peoples, and a few hundred plant species are more widely applied on an industrial scale. This number may increase as more knowledge about mire/wetland plants for medicine in tropical areas becomes available.

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[88] E.g. Schäfer & Degenhardt 1999.
[89] Succow 1988. For mire types, see § 2.3.
[90] E.g. imports from South- and East-European countries and from Turkey into Germany, cf. Schäfer 1999.
[91] Including reed (*Phragmites australis*), cattails (*Typha* spp., Theuerkorn et al. 1993, Wild et al. 2001, sedges (*Carex* spp.) and grasses (e.g. *Phalaris arundinacea*), alder (*Alnus*, Lockow 1997).
[92] Wichtmann et al. 2000.
[93] Wichtmann, 1999b.
[94] Wild et al. 2001
[95] Rodewald-Rodescu 1974, [Landström & Olsson 1998, Nilsson et al. 1998].
[96] Lange 1997, Soyez et al. 1998.
[97] Based on information collected by Thomas Heinicke. For information on plants in tropical peat swamp forests used for medicinal purposes see Safford & Maltby 1998.
[98] Cf. Van Os 1962, Riekstinsh 1986, Šimkusite 1986, Sotnik 1986, Elina 1993, Fuke 1994, Rongfen 1994, Hämet-Ahti et al. 1998, Safford & Maltby 1998.

Sphagnum plants – as excellent absorbents with antiseptic properties[99] - were used successfully as a substitute for cotton in surgical dressings in the Napoleonic and Franco-Prussian Wars[100], by the Japanese in the 1904 – 1905 war with Russia, and extensively by both sides during World War I[101].

In the former USSR about 40% of medicines were made from medicinal plants, half of them from wild plants. 234 wild species were used on an industrial basis, including 29 mire/wetland species (Table 3/10)[102].

Table 3/10: Order of magnitude of annually collected mire plant material for medicine in the former USSR (in 10^3 kg $year^{-1}$)[103].

vascular plant species	10^3 kg $year^{-1}$
Menyanthes trifoliata, Polygonum bistorta, Arnica montana	10 - 100
Acorus calamus, Althea officinalis, Frangula alnus, Nuphar lutea, Ledum palustre, Valeriana officinalis	100 - 1000
Vaccinium myrtillus, Vaccinium vitis-idaea	1000 - 10000

About 230 medicinal preparations are produced world-wide from Sundew (*Drosera*) species[104]. Quantities of various *Drosera* species on the European market are estimated to range from some hundred kg $year^{-1}$ (*Drosera intermedia, D. peltata*) to 7-10 tonnes $year^{-1}$ (*Drosera madagascarensis*)[105]. In the period 1981-1994, the quantity of *Drosera rotundifolia* collected annually from natural peatlands in Finland increased from 100 kg to 2100 kg[106].

In Canada Labrador Tea (*Ledum groenlandicum*) is used as a medicinal plant.

In countries where there has been destruction of mires the extent of local collection of mire plants for medical purposes has decreased. This leads to increased imports of mire plant products from countries where large areas of mires remain, which increases the pressure on the resources in those countries.

(d) Wild animals for food, fur and medicine[107]

Many fur-bearers such as coyote, racoon, mink and lynx and game species such as grouse, ducks, geese and moose are often found in peatlands. In North America, black bears, which are used for food and fur, as well as in traditional medicine (bladders), are also frequently found in peatlands. While these species do not depend

[99] Williams 1982, Verhoeven & Liefveld 1997.
[100] Varley & Barnett 1987.
[101] Porter 1917, Nichols 1918a, b, Thieret 1956.
[102] Chikov 1980.
[103] After Chikov 1980.
[104] McAlpine & Waarier Limited 1996.
[105] Kirsch 1995.
[106] Galambosi et al. 1998, 2000.
[107] North American information based on material from André Desrocher. European information based on material from Alexandr Mischenko and Tatiana Minaeva.

on peatlands for their survival this habitat may contribute substantially to their continued presence in populated regions where few areas other than peatlands provide safe havens away from direct human disturbance.

Peatlands may also be significant for fishery. In tropical peatlands, fish provide important proteins to local communities[108]. Many coastal tropical fish are highly dependent on mangroves for nursery, feeding, and spawning grounds.

(e) Peat substrates in situ

Some carrier functions (forestry, agriculture, horticulture) have been included under production functions because in their case it is difficult to separate the production and carrier functions.

(ea) Agriculture and horticulture in situ[109]

The capacity of peatlands for agricultural production depends on a number of natural and socio-economic factors. The natural factors include

- climatic conditions,
- the landscape position of the peatland,
- the type of peat deposit,
- the water and oxygen content of the soil,
- the physico-chemical properties of the soil,
- vegetation.

Climate: Climatic conditions impose the basic limitations on peatland agriculture. Cultivated plants require an adequately long vegetation period and a minimum amount of heat energy. Consequently the temperature conditions that are determined by the macroclimate of the region and modified by the microclimate of the peatland are decisive. The following factors make cultivation difficult or impossible:

- too short a growing period,
- a mean annual temperature which is too low,
- excessive variation between the mean temperatures of the warmest month (July) and the coldest month (January),
- excessive variations in temperature between day and night,
- frequent ground frosts,
- temperatures in the growing period which are on average too low.

Peatlands have a specific microclimate[110]. Compared with the surrounding area, a peatland has a greater variation in temperature, a higher frequency of frost occurrence and higher air humidity. The reason is that peatlands are usually found in terrain depressions (valleys, hollows) into which cooler air flows. As a consequence, the soils of both pristine and reclaimed peatlands are significantly cooler in summer than mineral soils, and the air temperature is also lower. The microclimate of peatlands thus creates significantly more severe climatic conditions for agricultural plants than the microclimate of the surrounding mineral soils. This results in agriculture on peatlands in the northern hemisphere taking place in more southern latitudes than

[108] Page & Rieley 1998, Ali 2000.
[109] Based on information from Piotr Ilnicki. Cf. also Okrusko 1996.
[110] See also § 3.4.3 (n): Regulation of regional and local climates.

similar agricultural activity on mineral soil. Cooler climatic conditions are more favourable for trees and shrubs and for meadows and pastures.

Landscape position: Depending on the location of the wetland in the surrounding terrain, the excess of water may be removed by gravity drainage or pumping. The drainage network is more intensive in deposits with a greater depth of peat and where there is spring water. Additional difficulties occur in flooded river valleys and in depressions. The more difficult and expensive the maintenance of the required ground water depth and of the moisture in the root layer of cultivated plants, the smaller the possibility of a permanent utilisation of the peatland.

Type of peat deposit: In the majority of European countries the utilisation of peatlands as arable land was thought to be advisable only on shallow (<1.0 m) and very shallow (<0,5 m) deposits, or as sand-cover cultivation. In Belarus, arable land was established on deep peatlands, and shallow areas were designated for use as grassland. Each country developed different methods for the drainage, fertilisation and use of peatlands.

In Europe, east of the Elbe river, agricultural use has been developed on fens which dominate in that area. In countries with a maritime climate, agriculture has been developed both on fens and raised bogs. In the Netherlands and Germany numerous methods of agricultural utilisation of peatlands were developed that involved a partial or total reconstruction of the soil profile (sand cover cultivation, deep ploughing). These methods usually led to an equalising of the air and water conditions throughout the soil profile, to an increased carrying capacity of the surface, to an improvement in the microclimatic conditions, and consequently to a significant increase in the yield of cultivated plants. These methods were used in the Netherlands and in north-west Germany on an area of over 300,000 hectares. As a result, the peatlands ceased to exist and in their place a specific type of organic soil developed.

In parts of Britain the practice of ‘warping’ transformed estuarine lowland peatlands into agricultural land by allowing sediment-rich water to flood peat-covered areas for extended periods, eventually covering the peat with a mineral soil layer. The result of this process can be observed in the Humberhead Levels of the Humber Estuary in the East of England[111].

Water and oxygen content: The air-water regime of a peatland soil plays a fundamental role in agricultural use. The peat-accumulation process can only be continued by maintaining a groundwater level close to the surface. The use of a peatland for meadow and pasture generally requires a lowering of the groundwater level to a depth of 0.4-0.8 metres below the surface. Its use as arable land requires the water level to be an even deeper 1.0-1.2 metres below the surface.

Physico-chemical properties: The physical and chemical properties of soils are most important in the surface layer of the peatland (to a depth of 0.3 metres) where the majority of roots of cultivated plants are found. These properties depend on:

- peat type,
- degree of peat decomposition,

[111] Based on information provided by Charlotte McAlister.

- ash content,
- peat reaction (pH),
- peat fertility (nutrient content),
- industrial contamination of the soil.

The first three factors determine the physical and water properties, the remaining factors control the conditions of plant growth and the quality of the yield.

Relatively favourable conditions for agricultural production are present in fens with a low or medium ash content and a small or medium degree of decomposition. Neutral and slightly acid reaction (pH 5.5-7.0), higher soil fertility and absence of industrial contamination (heavy metals, persistent organic pollutants) are commonly regarded as beneficial for agricultural production.

Sediments under the peat may contain significant amounts of sulphur (East England, Indonesia), or carbonates (Hungary, Poland). In shallow organic soils the reduction in the depth of the organic layer by mineralisation (see § 2.6[ii]) results in the rapid deterioration of plant growth conditions as the roots of cultivated plants do not usually penetrate to the very acid or alkaline soil layers.

- ***Europe:*** Approximately 14% of European peatlands are currently used for agriculture. Large areas of peatlands used for agriculture are found in Russia , Germany, Belarus, Poland and Ukraine (Table 3/11). In Hungary (98%), Greece (90%), the Netherlands and Germany (85%), Denmark, Poland and Switzerland (70%) the majority of peatlands are used for agricultural purposes. In these countries the high population density required that wetlands be used for food production. Proportional to the total area of peatlands, the use of peatlands for agriculture is small in Fennoscandia, the Baltic countries, Russia and the British Isles. The great majority of peatlands used for agriculture in Europe consist of meadows and pastures. The area of agricultural peatlands has decreased steadily in recent years for economic reasons and due to increasing nature protection.

Table 3/11 Peatland used for agriculture in some European countries**. To be examined against other data in this report**

Country (References)	Total peatland area (km^2)	Peatland area currently used for agriculture	
		km^2	%
Belarus – (Bambalov)	23 967	9 631	40
Czech Rep.+ Slovakia (Lappalainen)	314	ca 100	ca 30
Denmark (Aaby)	1 420	ca 1 000	ca 70
Estonia (Orru)	10 091	ca 1 300	13
France (Lappalainen)	ca 1 100	ca 660	ca 60
Finland (Vasander 1996)	94 000	ca 2 000	2
Germany (Steffens)	14 200	ca 12 000	85
Great Britain (Burton)	17 549	720	4
Greece (Christianis)	986	ca 900	ca 90
Hungary (Toth1983)	1 000	975	98
Iceland (Virtanen)	10 000	ca 1 300	13

Country (References) (continued)	Total peatland area (km^2)	Peatland area currently used for agriculture	
		km^2	%
Ireland (Shier)	11 757	896	8
Latvia (Snore)	6 691	ca 1 000	15
Lithuania (Tamosaitis et al)	4 826	1 900	39
Netherlands (Joosten 1994)	2 350	2 000	85
Norway (Johansen)	23 700	1 905	8
Poland (Ilnicki et al.)	10 877	7 620	70
Russia (Kosov et al.)	568 000	70 400	12
Spain (Lappalainen)	383	23	6
Sweden (Fredriksson)	66 680	3 000	5
Switzerland (Küttel)	224	ca 160	ca 70
Ukraine (Zurek)	10 081	ca 5 000	ca 50
Total	880 196	124 490	14

- ***Tropical agriculture***[112]***:*** While the peat in northern temperate regions is formed largely from grasses, sedges and mosses, tropical peat generally consists of a range of organic debris including trunks, branches and roots of trees.

  Indigenous peoples have had long experience in the reclamation and utilisation of peatlands for agriculture, particularly in the cultivation of horticultural crops. In areas which remain under tropical inundation beneficial products can be extracted from sago and other palms.

  Approximately 313, 600 hectares, or 32% of the peat areas in Peninsular Malaysia, are being utilised for agriculture, largely for estate crops[113]. In Indonesia large areas of peatlands have been cleared for agriculture-based transmigration settlement and for the expansion of estate crops.

  Lowland peat soils can be productive for wetland rice[114]. Good levels of productivity can be achieved with horticultural crops with intensive management. On small holdings (which in Indonesia, for example, vary from 0.6 to 2 hectares), an integrated system of animal husbandry (pigs, cattle poultry) and horticultural crops can provide subsistence. Sago palms grow naturally and are simple to cultivate and need little maintenance[115]. Sarawak is now the world's largest exporter of sago, exporting annually about 25,000 to 40,000 tonnes of sago products to Peninsular Malaysia, Japan, Taiwan, Singapore and other countries[116]. Palm oil trees, which have a shallow root system and need a higher soil nutrient level than sago[117], are successfully cultivated[118]. Other agricultural activities

112 Dent 1986, Radjagukguk 1991, Mutalib et al. 1991, Rieley 1991.
113 Leong & Lim 1994.
114 Cf. Shulan et al. 1994.
115 Stanton & Flach 1980.
116 http://www.econ.upm.edu.my/~peta/sago/sago.html
117 Matsumoto et al. 1998.
118 See for a cost-benefit analysis of sago and oil palm cultivation on peatlands: Kumari 1995 and http://www.econ.upm.edu.my/~peta/sago/sago.html

which can be carried out include buffalo farming and the growing of native species of fruit trees, pineapple, rubber, coconut, coffee and spices.

The greater part of Southeast Asian coastal peats have marginal physical properties for plant growth and, without careful management, crop yields are on average low.

- ***North America:*** Extensive areas of peatlands in North America are cultivated for agriculture. In Canada it is estimated that 40 000 hectares of peatland are under cultivation. The principal uses are vegetable production and pastureland. Cranberries are produced in British Columbia, wild rice is grown in Manitoba and peatlands in Newfoundland are used to grow forage crops[119]. The U.S.A. has 21 million hectares of peatlands, of which less that 10% have been cultivated for agriculture[120]. Over 230 000 hectares of fen peatlands are cultivated in the Florida Everglades, including large areas of sugar cane and rice. Other crops produced in the U.S.A. include vegetables, grass sods for use in lawns and cranberries[121].

  The commercial production of cranberries on peatlands in North America[122] is - with a production of 6 million barrels[123] - a major business enterprise[124]. This form of mono-cropping involving removal of wetland vegetation, re-profiling and periodic flood-harvesting, is very different from the wild berry collection from intact mires described in §3.4.1(ca) above. With the industry's intensive use of water and the application of fertilisers and pesticides in a wet environment, impacts on streams and lakes can be more direct than for other agricultural operations[125]. The consumption of cranberries is promoted for their medicinal values[126]. Expansion of cranberry cultivation on peatlands in other areas of the world[127] is currently being explored.

(eb) Forestry on mires and peatlands[128]

Intensity levels of utilisation: There are three intensity levels of the utilisation of mires for forestry (Table 3/12):

- In some parts of the world wood harvesting is practised on pristine peatlands. This type of utilisation is called 'exploitation'[129] but is referred to here as **transitory collection forestry**. As a consequence the tree growth and regeneration possibilities may be hampered due to a rise in the groundwater level after tree

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[119] Rubec & Thibault 1998, Zoltai & Pollett 1983.
[120] Malterer & Johnson 1998.
[121] Lucas 1982,Stewart 1991.
[122] Based on material from Charlotte McAlister.
[123] www.wiscran.org/whatshta.html
[124] Luthin 2000, Lochner 2000; www.oceanspray.com; www.cranberries.org; www.northlandcran.com; www.wiscran.org; http://omega.cc.umb.edu/~conne/marsha/cranintro.html;
[125] www.library.wisc.edu/guides/agnic/cranberry/dnrpaper.html
[126] www.oceanspray.com/uti_info.htm
[127] E.g. in Estonia (www.loodus.ee/nigula/kuremari/kuremari_e.html) and the Far East of Russia (www.iscmoscow.ru/english/main/rfe_tgp/projects/sg2-03.htm). It has proved to be commercially unsuccessful in Ireland due to the mildness of the climate and lack of sunshine – G McNally).
[128] Based on information from Juhani Päivänen.
[129] Because the words 'exploitation' and 'sustainable' are used in this document with defined meanings (see Glossary) different terms to those used in the industry have been used in this section.

harvesting, leading to decreasing yields. At the same time, however, the functioning of the mire ecosystem may continue.

- **Conserving management forestry** ('sustainable forest management') aims at maintaining the forest resource by applying proper natural regeneration of the tree stands on the sites which have been harvested.
- **Progressive management forestry** aims at increasing the forest resource by ameliorating the growing conditions in the site by drainage and fertilisation and by taking good care of the tree stand by proper silvicultural measures. This man-made disturbance in the peatland ecosystem has to be maintained if the increased levels of wood production on the site are to be maintained[130].

The forms of peatland utilisation for forestry vary from country to country depending on such factors as demand for raw wood, silvicultural management practice and tradition and infrastructure of the countryside. In some countries peatland forestry may still be at the '**transitory collection forestry**' stage although the importance of '**conserving management forestry**' is generally admitted. In countries like Finland the approach to the utilisation of peatlands for forestry has for decades been not only '**conserving**' but '**progressive management forestry**', minimising harmful effects on the site and on stream water.

Table 3/12 Intensity levels of mire utilisation for forestry[131].

Forestry type	Industry term	Forest management activities	Wood resource / yield
Nature conservation		None	wood resource not used
Transitory collection forestry	Exploitation	Tree harvesting without adequate care taken of regeneration	continuous wood yield reduced
Conserving management forestry	Sustainable forest management	Tree harvesting with proper natural or artificial regeneration	continuous wood yield maintained
Progressive management forestry	Progressive management forestry	Site amelioration (drainage, fertilisation), (afforestation), thinnings, ditch cleaning etc., final harvest ,and regeneration	continuous wood yield increased

***Forest on pristine mires*:** On pristine mires several factors (climate, excessive water, deficiency of nutrients) may restrict the productivity of tree species. However, some forested mire sites support commercial-size tree stands. In a typical pristine-mire tree stand the number of stems is high in small diameter classes and decreases abruptly with increasing diameter. The result is that on pristine mires the tree stands have an uneven age structure. There is also some variation in the density of the tree stands.

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130 Päivänen & Paavilainen 1996.
131 Changed after Päivänen & Paavilainen 1996.

In Fennoscandia nutrient-rich mire sites are usually dominated by Norway spruce (*Picea abies*), although the proportion of hardwoods, mainly pubescent birch (*Betula pubescens*), may be considerable. In nutrient-poor mire sites Scots pine (*Pinus sylvestris*) predominates and in ombrotrophic sites it is the only tree species. In the boreal zone of North America black spruce (*Picea mariana*) is the predominant tree species on mires and occurs alone or mixed with tamarack (*Larix laricina*) or eastern white cedar (*Thuja occidentalis*). In western parts of Canada, lodgepole pine (*Pinus contorta*) is also of economic importance on mires[132].

Forest management on pristine mires: Forest management on pristine mires belongs to the categories of '**transitory collection forestry**' or at its best '**conserving management forestry**' (Table 3/12). To maintain a continuous yield the cuttings should be "light", to prevent the site from becoming wetter due to a rise in the groundwater level. Pristine forested mires may be one of the few cases where management to promote uneven-aged stand structure might be recommended (so-called single-tree selection for continuous cover). Very little commercial tree harvesting is carried out on pristine forested mires in Fennoscandia which are dominated by Norway spruce (*Picea abies*) or Scots pine (*Pinus sylvestris*), because single-tree harvesting is not economic[133]. A private landowner may, however, harvest trees from his wetland property to be used for fuel or construction on his own farm.

In North America harvesting and regeneration of black spruce (*Picea mariana*) is significant, especially in Ontario and Québec, Canada. It forms a major source of fibre for the pulp and paper industry. A large proportion of black spruce comes from forested mires, in which it is important to minimise damage to the soil because of the lack of forest drainage. The preservation of advanced growth[134], mainly black spruce layerings[135], is an essential feature of regeneration of forested mires. On sites without sufficient advanced growth good results have been achieved with both seed-tree groups[136] and clearcut strips[137].

It is typical of the peatland forestry in Ontario that intermediate ("thinning") cuttings and tending of young stands are seldom practised. However, Canadian forestry is gradually changing from '**transitory collection forestry**' towards a planned utilisation of forest resources ('**conserving management forestry**')[138].

Tropical forestry: The natural vegetation of tropical peatlands is mainly forest. In Southeast Asia tropical forest covers extensive tracts of peatlands, mainly between coastal mangroves and the terrestrial rain forest. Most of the tree families of lowland rainforest are found in peatland forests but with fewer species. Peatland forest has a lower and more open tree canopy than terrestrial rainforest. It consists of a connected series of forest types which replace each other from the peatland perimeter to its centre. It includes substantial quantities of commercial tree species and yields some

[132] Paavilainen & Päivänen 1995, Päivänen 1997.
[133] Paavilainen & Päivänen 1995.
[134] "Advanced growth" consists of almost mature trees growing beneath the forest's canopy.
[135] http://www.na.fs.fed.us/spfo/pubs/silvics_manual/Volume_1/picea/mariana.htm.
[136] Areas cleared of trees except for small groups of seed-bearing trees.
[137] Strips cleared of trees. Jeglum & Kennington 1993.
[138] Jeglum & Kennington 1993.

of the most valuable tropical timbers. Ramin (*Gonystylus bancanus*) and agathis (*Agathis dammara*), for example, contribute almost 10% of Indonesia's exports of forest products[139]. Although peat swamp forests produce a smaller number of large trees per hectare compared to other lowland forests, several commercially important timber species, such as ramin and some meranti (*Shorea* spp.), are restricted to this forest type[140]. Peatland forest is exploited in much the same way as terrestrial forest, but allowing for the lower bearing capacity of the soil. There are two types of exploitation – **transitory collection** (even destructive) forestry; and **conserving management forestry**[141].

The most frequent destructive logging operations have been concentrated in peatland forests earmarked for agriculture[142]. In other areas such forest has been damaged by logging concessions issued without detailed environmental assessments conducted in advance, and by illegal logging.

A **conserving management forestry** form of selective timber extraction is carried out using minimal mechanisation under assumptions as to the regeneration cycle of commercial species. An example of such cropping is in Sarawak. Oldgrowth peatland forest is worked on a harvesting period of 45 years. Each group of permanent forest areas constitutes a unit managed under a Regional Management Plan. An annual cut is prescribed for each area. Logging is carried out manually. Damage to land is minimised. Silvicultural treatments are carried out after logging. While the felling cycle is set at 45 years the time of subsequent cuts is dependent on the rate of re-growth of the forest[143].

Forest drainage: On a global scale the proportion of the total terrestrial wetland (including peatland) area drained for forestry is less than 3%. The area under forest utilisation without drainage has not been estimated. The current practice and extent of drainage ('**progressive management forestry**') in different countries varies considerably depending on the potential wetland area, the structure of land ownership, the demand for raw wood and national economic considerations[144] (Table 3/13).

In maritime climates such as those of the British Isles, drainage and afforestation with lodgepole pine (*Pinus contorta*) and Sitka spruce (*Picea sitchensis*) is a common practice on treeless mires. The long-term prospects for forests on drained peatlands are reported to be good. Yields from the second rotation seem to be even higher than from the first[145]. In Fennoscandia peatland afforestation is nowadays restricted to cut-away peatlands and abandoned farmland on peat soil[146]. Drainage of new areas in Russia has practically stopped[147].

Most of the drainage in Fennoscandia, Russia and the Baltic states has been of naturally tree-covered mires. The profitability of drainage is dependent on the fertility

139 Laurent 1986.
140 Page & Rieley 1998, 1999.
141 Rieley 1991, Rieley et al 1997.
142 Ibrahim & Hall 1991.
143 Lee 1991.
144 See also Paavilainen & Päivänen 1995.
145 Pyatt 1990
146 Kaunisto 1997, Sundström 1997
147 Konstantinov et al. 1999

of the site, the volume of the tree stand capable of response at the time of draining, the geographical location of the site, and the price of wood. In general, drainage becomes more profitable with increasing site fertility, with a larger volume of original tree stand, and (in the Northern Hemisphere) the further south the site is located. On over 1 million hectares of the drained area in Russia, the drainage canals no longer function because of neglect, the activities of beavers, or infrastructure (such as roads and pipelines) which disrupt drainage. As a result this land is currently re-paludifying[148].

An attempt has also been made to estimate the profitability of forest drainage by calculating the inputs (all cost factors) and outputs (the increase in volume of wood cut multiplied by the price of wood). On this basis the internal rate of return on Finnish forest drainage activity would lie somewhat above 5%[149]. Canadian calculations show that drainage of an existing stand is economical if it can reduce the rotation age by 30 years or more[150]. Forest drainage has been shown to be profitable only if directed towards appropriate sites. This man-made disturbance in the peatland ecosystem has to be maintained if it is wished to maintain increased levels of wood production on the site.

Based on figures for Finland, some 20% of wood harvested on peatlands is used for furniture and construction, the remainder as raw material for pulp and paper mills. A very small proportion goes to energy wood[151].

Table 3/13 Estimates of terrestrial wetlands (incl. peatlands) drained for forestry[152]

	km^2
Finland	59,000
Russia	38,000
Sweden	14,100
Norway	4,200
Estonia	4,600
Latvia	5,000
Lithuania	5,900
Belarus	2,800
Poland	1,200

[148] Konstantinov et al. 1999. Vomperskij (1999) even states that half of the ca. 6 million hectares drained for forestry is currently re-paludifying.
[149] Heikurainen 1980.
[150] Payandeh 1988.
[151] Personal communication from V Klemetti; Annual Report of Vapo Oy 1998, p.9. J Päivänen (personal communication) states that there are no statistics dividing cutting removals between mineral soil and peatland. The actual cutting removal from all Finnish forests in 2000 was 61.5 million cubic metres, of which about 47 % was raw material suitable for sawn timber (Finnish Forest Research Institute 2001, p. 153). It has been estimated that the maximum sustainable removal (million m^3 per year) for mineral soil sites is 58.3 and for peatlands 9.7 for the period of 1996-2005. That would mean that 14.3 % of the total removal could be harvested from peatlands. The percentage estimated to come from peatlands is estimated to increase to 24.3 % in the period 2016-2025.(Nuutinen et al. 2000).

[152] After Paavilainen & Päivänen 1995.

	km^2
Germany	1,100
United Kingdom	6,000
Ireland	2,100
P.R. of China	700
USA	4,000
Canada	250
Total	148,950

3.4.2 Carrier functions

The carrier functions of mires and peatlands include all those functions for which they provide space and/or a suitable substrate. Because they lie in basins and are very extensive many mires and peatlands provide suitable locations, or bases, for water reservoirs and pisciculture. Their location and size and the fact that they are largely uninhabited can make them suitable for establishing towns, roads and harbours; as sites for waste disposal; and for military exercises.

(f) Water reservoirs (for recreation, hydro-electricity, drinking water)[153]

Reservoirs created for the production of hydro-electric power now cover extensive areas. Reservoirs cover 1.5 million km^2 globally, of which 0.9 million km^2 occur in temperate, boreal and subarctic regions[154].

Many of these temperate, boreal and subarctic reservoirs have flooded substantial areas of wetlands and peatlands, because they occupy the lower-lying positions in the landscape and because wetlands and peatlands cover a large proportion of the landscape in these regions. Water reservoirs in Belarussian Polesye, for example, cover some 400 km^2 of largely peat-covered areas[155]. It is estimated[156] that the 20,000 km^2 of reservoirs in Canada may have flooded 7,500 km^2 of wetlands and peatlands. In Finland approximately 900km^2 of peatland are covered with reservoirs[157]. Before inundation, these peatlands were generally sinks of carbon dioxide and sources of methane to the atmosphere. There is evidence that flooding converts peatlands from a sink to a source of carbon dioxide and increases the emission of methane to the atmosphere. See §§ 2.5 and 3.4.3(m).

(g) Fish ponds (Pisciculture) [158]

Peatlands have been inundated for commercial fish farming particularly in central Europe and China[159]. In Belarussian Polesye 200 km^2 of fishponds have been created largely on peatlands[160]. In what is now the Czech Republic fish ponds covered an

[153] Based on information provided by Tim Moore. See also Rubec & Thibault 1998.
[154] St. Louis et al. 2000.
[155] Pikulik et al. 2000.
[156] Roulet 2000.
[157] Virtanen & Hänninen 2000.
[158] Based on information from Jan Pokorny.
[159] Rongfen 1994.
[160] Masyuk 2000, Pikulik et al. 2000.

area of 1,600 km^2 at the end of 16^{th} century. Many ponds were later converted into agricultural land. The total area nowadays is 500 km^2, of which 15% is mostly situated on peatland. Fish species like Perch (*Perca fluviatilis*), Powan (*Coregonus lavaretus*), Peled (*Coregonus peled*), Brook Trout (*Salvelinus fontinalis*), and Trout (*Salmo trutta*) tolerate a relatively low pH and are suitable for cultivation in such ponds with a peat bottom. As water which is too acid can kill the fish stock, lime is often applied in places where water from surrounding bogs flows into the pond. Liming, discharges from agricultural ditches, and sewage can result in a fast decomposition of peat, resulting in a high consumption of oxygen, a release of phosphorus and other nutrients from the decomposing anaerobic peat, and a vigorous growth of algae. When dense stocks of fish are present, the euphotic zone (the upper layer of water that receives sufficient light for the growth of green plants) becomes shallow (0.5 – 0.1 m) and anaerobic conditions in and above the bottom prevail. The oxygen deficits may lead to sudden fish kills. West Lake near Hangzhou (East China) is an example of peat degradation after the discharge of non-treated waste water from the town (1 million inhabitants) into the lake (560 ha), which was known as a national beauty spot. The bottom has become anaerobic, Cyanobacteria ("blue greens") develop, and H_2S and methane are released from a 0.5 – 1 metre layer of decomposing peat on the bottom.

Large stocks of carp combined with liming and organic fertilising change a peat pond ecosystem poor in plant nutrients into a fish pond with excess nutrients, one that is only suitable for carp production.

Fishing lakes have been excavated from cutaway peatland in Ireland and are in active use for recreational fishing[161].

(h) Urban, industrial and infrastructural development[162]

Substantial peatlands and mires are located in coastal areas, where over 50% of the world's population lives. Major cities like Amsterdam and St. Petersburg are largely build on peat. Location near to coastlines makes it tempting to convert mires and peatland to provide infrastructure for towns, roads and harbours so that these areas can become triggers for the development of regions and countries. Mires and peatlands which represent extensive areas of largely uninhabited land and whose value as real estate is low are obvious targets for land-use planners and developers.

Blanket peatlands in Ireland and Britain[163] are in use for wind farms. Large tracts of peatlands in North America and West-Siberia are used for oil and gas exploitation infrastructure[164]. The Great Vayugan Mire (Novosibirsk and Tomsk Oblast, Russia) is designated as a drop zone for rocket stages from the Baykonur space launching facility in Kazakstan.

(i) Waste deposits / landfill[165]

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[161] Information provided by Gerry McNally.
[162] Based, inter alia, on information from Herbert Diemont.
[163] Butcher et al. 1995.
[164] Radforth & Burwash 1977, Meeres 1977.
[165] Based on information from Charlotte McAlister and Gerry McNally.

The vast quantity of domestic and industrial waste produced daily and its concentration in urban areas creates major disposal problems. Transport is expensive and it is desirable for municipal authorities to dispose of waste close to its source. However land values in urban areas are usually inflated and space is at a premium. Wetlands, especially peatlands, often in estuaries close to urban areas (as is common in the Pacific North West of the USA and Canada), are often the last areas to be developed given the high cost and technical difficulty of building in such wet areas. They also have lower land purchase costs. These factors make them obvious targets for waste disposal. The form of 'landfill' most commonly employed has been to place refuse on top of the mire surface compressing the peat and forcing groundwater to discharge from the water body. This is effectively 'pre-stressing' as practised in most forms of construction on soft or wet land. A direct result is often local flooding, and longer-term results can include contamination of ground and surface water by landfill leachates. Poor understanding of the dynamics of water movement in mires has led in many cases to the conclusion that they are absorbent 'sinks' and that any leachates will be contained within the site - which is not the case. Peat soils have often been proposed as natural barriers for the disposal of sewage sludge, mine tailings leachate etc, because of their high absorption capacity in particular for heavy metals. See also § 3.4.3(p).

In terms of more modern forms of waste disposal (including segregation, re-cycling, composting, incineration and landfill in sealed units) peatlands (both pristine and industrial cutaway) have three advantages:

- they often are very extensive in area (and thus can cope with the volumes involved),
- they tend to be in more remote areas, with only sparse human habitation in the vicinity (thus avoiding some of the conflicts with local communities), and
- they often constitute borders between political/administrative areas (being seen, therefore, as nobody's responsibility).

(j) Military exercises and defence[166]

Military training grounds necessarily cover large expanses of land. The potentially dangerous nature of military exercises requires them to take place in remote areas such as peatlands which are away from centres of population. This is especially the case in upland areas where rugged terrain make them ideal locations for military training grounds.

Areas which have been reserved entirely for military exercises often include peatlands of high conservation value. These areas are unlikely to have been drained to improve agricultural potential, overgrazed or utilised for peat removal, so that in various densely populated countries many of the best and most intact mire sites are found within such reserves[167]. The main differences between these sites and surviving mires

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[166] Based on information from Charlotte McAlister. See also Gorissen 1998, Baaijens 1982, Karofeld 1999.

[167] Examples: Within two military training grounds in the North of England (RAF Spadeadam and Otterburn Training Area), 'notified' mires include a Ramsar site, Sites of Special Scientific Interest (a UK classification), National Nature Reserves and Special Areas of Conservation (a European Union designation) covering several thousand hectares (personal communication from Charlotte MacAlister).

outside of military zones are severely restricted access; limited development or habitat alteration; and minor disturbance mainly in the form of abandoned ordnance. Restricted access has in many cases protected sensitive sites from disturbance, and damage by vehicles is often limited as wet areas are generally avoided.

The difficulty in accessing peatlands and their impenetrability to heavy equipment have always given them an important role in military defence. The present Groote Peel National Park (the Netherlands) was saved from complete land reclamation in the 1930s because the bog wilderness constituted a part of the Peel-Raam defence line between Belgium and the river Meuse[168]. Similarly in the 1952 Soviet plan for draining the Pripjat marshes, the significance of the area as a factor against possible future invasion from the west was taken into consideration, and contingency provisions for emergency re-flooding of the area were included in the plan[169].

(k) Prisons

Because of their inaccessibility and isolated location, peatlands have often been used to site prisons and labour camps. Examples include Veenhuizen in the Fochtelo peatland (the Netherlands), the Nazi concentration camps Dachau and the Esterweger Dose/Papenburg complex (Germany), Dartmoor (Britain) and various camps of the Gulag Archipelago (Soviet Union).

(l) Transport and herding[170]

Frozen mires in northern countries are used for the transport of forestry products. They are also used by nomadic peoples to herd reindeer to and from summer grazing grounds. Because of their natural openness, peatlands are also favoured areas for cross-country skiing.

3.4.3 Regulation functions

The term ‘regulation function’ summarises all the processes in natural and semi-natural ecosystems which contribute to the maintenance of a healthy environment by providing clean air, water and soil[171]. The processes involved can be of biological, biochemical or physical origin. Peatlands have a function in the regulation of essential environmental processes and life support systems; i.e. in the maintenance of adequate climatic, atmospheric, water, soil, ecological and genetic conditions. They may provide clean water, regulate water flow, recycle elements and affect both local and global climates.

The most extensive remaining largely intact bog area in Central Europe is the Tinner Dose, since 1876 a military terrain (Gorissen 1998). Similarly one of the best bog remnants in the Netherlands, the Witterveld, is situated in a military exercise area (Baaijens et al. 1982).

[168] Hamm 1955, Joosten & Bakker 1987, Michels 1991.

[169] Kazakov 1953.

[170] Based on information provided by Reidar Pettersson.

[171] De Groot 1992.

(m) Regulation of the global climate[172]

Although carbon dioxide emissions from human activities make up only a small fraction of the carbon that cycles annually among the atmosphere, terrestrial plant and animal life, and oceans, these emissions account for the unwanted build-up of atmospheric CO_2. Reducing the emissions associated with energy production and land use should moderate the rate and reduce the ultimate magnitude of climate change[173].

Mires act as sinks of atmospheric carbon dioxide and peatlands constitute large reservoirs of carbon and nitrogen. Both pristine mires and re-wetted peatlands emit methane and nitrous oxide. Drained peatlands emit carbon dioxide. Because of their extent and the large volumes of carbon stored in their peat, mires and peatlands play a major role in the global carbon balance. This section discusses how peatlands and their use may influence the global climate. It is a summary of material in Appendix 1. The statements in this section are supported by the text, tables, figures, and references in Appendix 1. The section is based on information as it is known at the time of writing of this document. Future research will add to this knowledge.

Introduction: The peat formation process is strongly influenced by climatic conditions, but mire ecosystems themselves also affect the global climate. The natural effect of climate on mires and mires on climate occurs through the so-called greenhouse gases which mires absorb and emit, and the carbon they store.

Like a window pane in a greenhouse, a number of gases in the atmosphere allow solar radiation (visible light) to pass to the surface of the earth while trapping infrared (heat) radiation that is re-emitted by the surface of the earth. This trapping of heat radiation, that would otherwise escape to space, is referred to as the greenhouse effect. Gases that influence the radiation balance are called radiatively active or greenhouse gases (GHG)[174].

Greenhouse gases fall into three categories:

- radiatively active gases such as water vapour (H_2O), carbon dioxide (CO_2), ozone (O_3), methane (CH_4), nitrous oxide (N_2O), and the chlorofluorocarbons (CFCs) which exert direct climatic effects,
- chemically/photochemically active gases such as carbon monoxide (CO), nitrogen oxides (NO_x), and sulphur dioxide (SO_2) which exert indirect climatic effects through their influence on the atmospheric concentrations of hydroxyl radicals (OH), CH_4 and O_3, and
- aerosols: 10^{-6} - 10^{-2} mm large fluid or solid particles dispersed in the air.

Even without human interference the natural greenhouse effect keeps the Earth's surface some 30^0 C warmer than it would be if all solar radiation were transferred back to space. Water vapour, carbon dioxide and clouds contribute roughly 90 percent to the natural greenhouse effect; and naturally occurring ozone, methane and

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[172] Based on information supplied by Heinrich Höper.
[173] http://www.wri.org/climate/sinks.html
[174] Because the concentrations of natural greenhouse gases and those caused by human activity are small compared to the principal atmospheric constituents of oxygen and nitrogen, these gases are also called trace gases.

other gases account for the remainder. The emission of greenhouse gases resulting from human activities causes a change in the radiation balance of the Earth (radiative forcing).

Carbon exchange: A major characteristic of mires is that they sequester, or capture, carbon dioxide from the atmosphere and transform it into plant biomass and eventually peat. Mires and peatlands also emit greenhouse gases. The type of gases that mires and peatlands thus exchange with the atmosphere is not always the same. Different mire types emit different amounts and proportions of gases. In the course of their long-term development, some mire types become spontaneously wetter and the proportion of emitted methane consequently increases. Peatland drainage generally increases carbon dioxide emissions and decreases those of methane, and peatland agriculture additionally increases emissions of nitrous oxide. As all these gases have a different radiative forcing, their effect on the radiation balance of the atmosphere differs with the type of mire or peatland and the type of exploitation[175].

Carbon stores: The other important aspect of mires and peatlands is their function as stores of carbon. This is carbon that is excluded from short-term (e.g. annual) carbon cycling. Stores are only important when their volumes change. The increase of atmospheric carbon dioxide in the recent past has been caused principally by burning long-term carbon stores (fossil fuels such as coal, lignite, gas, and oil). The felling and burning of tropical rainforest increases carbon dioxide concentrations in the atmosphere because of the mobilisation of the carbon stored in forest biomass, not because plant productivity decreases.
The carbon store in peatlands can be subdivided into three components:

- the carbon store in the biomass,
- the carbon store in the litter, and
- the carbon store in the peat.

Each of these components may behave differently under different management options (such as agriculture, forestry, extraction, in fires, and under re-wetting).

To understand the integrated effects of peatlands on climate, and the consequences for climate of human impact, it is therefore necessary to consider both

- the types, volumes, and proportions of greenhouse gases exchanged, and
- the carbon stores in peatlands.

The role[176] of pristine mires: As stated above, mires sequester carbon dioxide from the atmosphere and transform it into plant biomass that is eventually stored as peat. Peat accumulation in mires is the result of various processes including carbon sequestration by plant photosynthesis (primary production), direct carbon losses during litter decomposition, decomposition in the acrotelm, and decomposition losses in the catotelm. Only about 10% of the primarily assimilated carbon is sequestered in the peat in the long term. Annual long-term carbon accumulation of the world's mires is approximately 1% of the carbon emitted by global fossil fuel consumption in 1990, or 10% of the carbon emitted by USA electricity utilities in 1998.

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[175] As defined in the Glossary.
[176] References to 'role' in this and the paragraphs which follow are to role in the regulation of the global climate.

In the long run, mires withdraw enormous amounts of carbon dioxide from the atmosphere and store it as peat deposits. At present approximately the same amount of carbon is stored in the world's peatlands as in the whole atmosphere. The decreasing atmospheric concentrations of carbon dioxide during interglacial periods as a result of peat formation, and the consequent steadily reducing greenhouse effect, is seen by some scientists as a major cause of the origin of ice ages.

Pristine mires affect the global climate both by the sequestration of carbon dioxide from the atmosphere and by the emission of other gases, especially methane and nitrous oxide.

Methane is the second most important greenhouse gas after carbon dioxide and is expected to contribute 18% of the total foreseen global warming over the next 50 years, as opposed to 50% attributable to carbon dioxide. Furthermore methane participates in tropospheric ozone formation. Global methane production is dominated by natural wetlands, rice paddies, and animal livestock. Methane emissions in mires are highly variable, but are generally higher in pristine fens than in pristine bogs.

Nitrous oxide is a greenhouse gas and also causes destruction of stratospheric ozone. Nitrous oxide emissions from pristine mires are low. Occasionally such mires may even consume nitrous oxide due to the reduction of nitrous oxide to dinitrogen (N_2) under conditions of severe oxygen deficiency.

Because all gases have a different lifetime in the atmosphere and a different "global warming potential", the combined effects of all three gases together depend on the time horizon chosen. On a 100-year horizon, for example, Finnish undisturbed mires increase the greenhouse effect, whereas on a 500-year horizon they decrease it. This is due to the changing impact of methane emissions (cf. Table 3/14).

Table 3/14: The atmospheric lifetime and the IPCC (1996) accepted global warming potentials over different time horizons of radiatively important gases[177].

Chemical species	**Atmospheric lifetime (years)**	**Global warming potential (mass basis) (time)**		
		20-year horizon	100-year horizon	500- year horizon
CO_2	variable	1	1	1
CH_4	12 ± 3	56	21	6.5
N_2O	120	280	310	170

Recent general overviews indicate that over a short time-scale (cf. Table 3/15) pristine mires contribute to the greenhouse effect with respect to their carbon dioxide, methane and nitrous oxide balance. Over a 500-year time-scale pristine bogs have a negative global warming potential and fens a small positive potential.

[177] Crill et al. 2000.

Table 3/15: Global Warming Potential (GWP in kg CO_2-C-equivalents ha^{-1} $year^{-1}$) of pristine mires using different time scales[178].

		bogs	fens
CO_2 sequestration (kg C ha^{-1} $year^{-1}$)		-310	-250
CH_4 emission (kg C ha^{-1} $year^{-1}$)		53	297
N_2O emission (kg N ha^{-1} $year^{-1}$)		0,04	0,1
Global Warming Potential	20 years	723	5524
Global Warming Potential	100 years	45	1724
Global Warming Potential	500 years	-233	173

Although it should be recognised that there are large uncertainties in these calculations, we may provisionally conclude that

- under the present climatic conditions,
- on a time scale relevant for current civilisation, and
- with respect to the combined effects of carbon dioxide, methane and nitrous oxide exchange,

pristine mires play an insignificant role with respect to global warming.
In this respect, mires do not differ from virgin tropical rainforests and other types of "climax" ecosystems that are in equilibrium with climate. Similar to these other ecosystem types that have a large carbon store in their biomass, mires and peatlands have a considerable climatic importance as *stores* of carbon, especially in their peat.

Recently it has been acknowledged that many other greenhouse gases are emitted by mires including

- Hydrocarbons that may significantly impact ozone, methane and carbon monoxide in the troposphere. Plants, primarily trees, emit an amount equivalent to all methane emissions. As the emissions are sensitive to temperature, the emissions from peatlands in North America and Eurasia are expected to significantly increase under global warming.
- Dimethyl sulfide (DMS CH_3SCH_3), an "anti-greenhouse gas" that enters the troposphere and is oxidised there to sulfate particles, which - as cloud condensation nuclei - influence cloud droplet concentrations, cloud albedo and consequently climate.
- Methyl bromide (CH_3Br) and methyl chloride (CH_3Cl) that have a cooling effect through their ability to destroy stratospheric ozone.

No quantitative information is available on the global climatic effects of these substances.

The role of drainage; agriculture: When virgin peatlands are converted to agriculture, the natural biomass is replaced by crop biomass. This may result in substantial changes in the *biomass* carbon store, e.g. when tropical forested peatlands

[178] Heinrich Höper (see Appendix 1).

are converted to vegetable or rice fields. A change of non-forested virgin peatland to grasslands and arable fields will generally not lead to such large biomass or litter changes.

The dominant effect of peatland drainage for agriculture is that the peat is exposed to oxygen which leads to peat mineralisation. This causes a decrease in the *peat* carbon store and an increased emission of carbon dioxide, especially in summer.

Under tillage, peat mineralisation is accelerated as compared to grassland due to more intensive aeration. Carbon dioxide emissions in arable fens are higher than in bogs.

Methane emissions from drained peatlands are generally very low though some emissions have been observed in bogs. Drained fens emit less methane than bogs and function more frequently as net sinks for atmospheric methane.

Nitrous oxide emissions from bogs are low due to the low pH and low total nitrogen content. In the more nutrient-rich fens somewhat higher nitrous oxide emissions have been observed. Nitrous oxide emissions depend on the available nitrogen and therefore on nitrogen fertilisation. It is assumed that 1% of the nitrogen applied as fertiliser is emitted as nitrous oxide.

Figure 3/2 gives an overview of the global warming potential of drained peatlands under different forms of agricultural use. Carbon dioxide is by far the most relevant gas, contributing between 85 and 98 % of the cumulative global warming potential of all greenhouse gases. Intensively used bog grasslands have a similar warming potential to that of tilled bogs. Fertilisation and liming of grasslands strongly increases peat mineralisation.

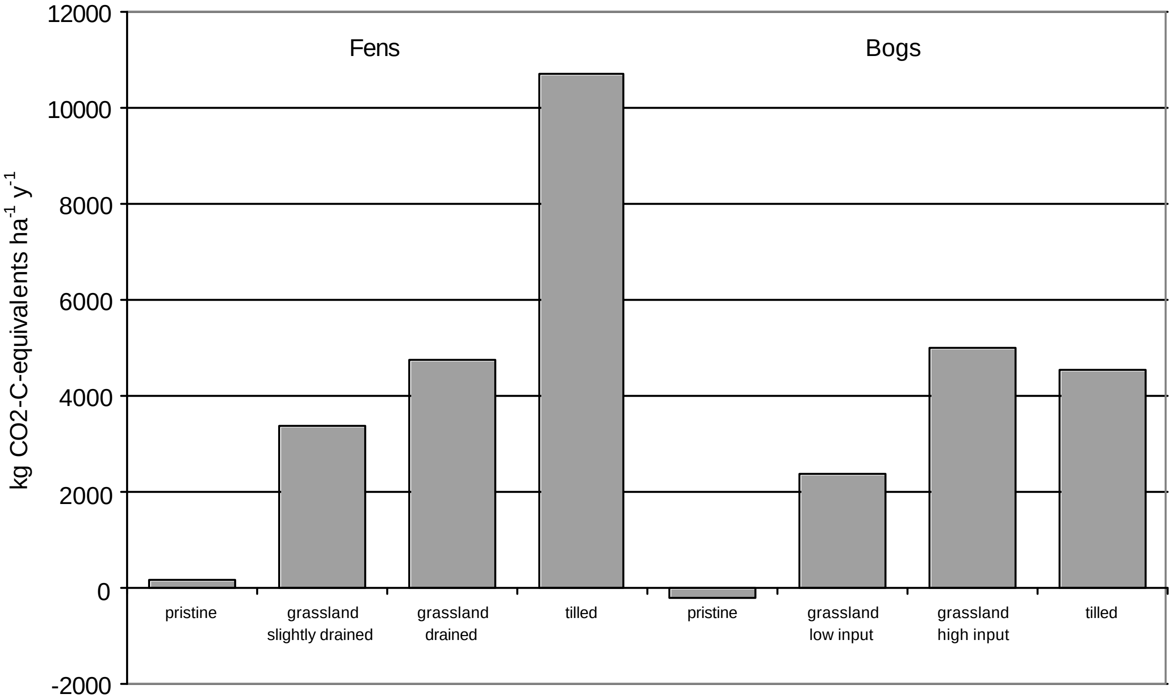

Figure 3/2: Rough estimates of the global warming potential of fens and bogs (in kg CO_2-C-equivalents ha^{-1} y^{-1}) under different types of land use (compiled by Heinrich Höper 2000).

The role of drainage; forestry: The effect of peatland drainage for forestry[179] is more complicated than that of agricultural drainage, as various processes with contrasting effects occur simultaneously and the integrated effects differ considerably over different time-scales.

As in agriculture, increased aeration of the peat after forestry drainage results in faster peat mineralisation and a decrease in the *peat* carbon store. In the boreal zone this aeration may be accompanied by a decrease in peat pH and a lower peat temperature, which may again reduce the rate of peat mineralisation.

As water-logging in mires generally prevents an economic level of wood production, peatland drainage aims to increase the wood yield (see § 3.4.1 [eb]). After drainage, forest vegetation (such as trees and shrubs) takes the place of the original mire vegetation and the peatland *biomass* carbon store (both above and below ground) increases quickly. This store would eventually reach a new equilibrium much higher than that of the former mire vegetation. Before this stage is reached the wood is harvested and the biomass store reduces substantially again.

Peatland drainage for forestry also leads to changes in the *litter* carbon store. The moist litter in the mire's acrotelm is generally considered as part of the peat carbon store as it gradually passes into the catotelm peat. The litter in a drained forest[180] is of different quality and can be considered as a separate component. The accumulation of

[179] The complexities associated with peatland drainage are excellently reviewed for the boreal zone in Crill et al. 2000, (cf. also Joosten 2000), on which this subsection is largely based.
[180] In the boreal zone consisting of remains of conifer needles, branches, rootlets, forest mosses etc.

litter leads to an increase in the litter carbon store. As this litter accumulates under aerobic conditions, the litter carbon store eventually reaches an equilibrium and the net accumulation stops. Depending on the peatland type and the cutting regime of the forest, it might take centuries before this equilibrium is reached.

Peatland drainage for forestry therefore leads to

- a steady decrease of the *peat* carbon store,
- a rapid initial increase of the *biomass* carbon store, the harvesting of which leads to a substantial reduction, and
- a slow initial increase of the peatland *litter* carbon store which eventually, after some centuries, reaches an equilibrium.

Thus, the *peatland* carbon store, being the combined effect of these processes, varies strongly in time. In the first period after drainage, the increase in biomass and litter stores may strongly exceed the losses from the peat carbon store. As the biomass and litter stores tend to an equilibrium, but the peat carbon losses continue[181], the cumulative carbon losses from peat oxidation prevail in the long run.

With respect to gas exchange, the drainage of peatlands for forestry generally leads to an increase in carbon dioxide emissions, a substantial decrease in methane emissions and, depending on peatland type and type of land use (fertilisation), to a sometimes drastic increase in nitrous oxide emissions.

Peat extraction: The effect of peat extraction and subsequent oxidation is similar to that of burning fossil fuels[182]. The peat carbon store is largely transformed into carbon dioxide. Efficient drainage in the extraction areas may maintain high rates of carbon dioxide emissions while methane and nitrous oxide emissions remain fairly low.

Integrated effects: Detailed national balances with respect to peat carbon stores and radiative forcing are available only for Finland. In Finland both undisturbed and forestry drained peatlands currently have a positive carbon balance, the former because of *peat* accumulation, the latter because of an increase in root *biomass* and *litter* carbon. Table 3/16 presents the ***integrated effects*** of various greenhouse gases on radiative forcing. The strongly time-dependent effect of undisturbed mires is striking, because of the decreasing effect of methane. Estimating the effects on a 500-year horizon is even more speculative than doing so on a 100-year horizon, and does not take into account changes in hydrology and temperature resulting from global climate change.

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[181] Provided that the forest management continues and the peatland remains sufficiently drained.
[182] In case of agricultural and horticultural use, the peat is oxidised more slowly.

Table 3/16: Summary of radiative forcing of Finnish peatlands under different land-use forms using different time horizons.

		Radiative forcing (in 10^{12} g CO_2 equivalents)	
Land use	**area in 1000 ha**	**100 year horizon**	**500 year horizon**
Undisturbed peatlands	4000	+ 8.40 ± 0.15	- 0.54 ± 0.15
Forest drained peatlands	5700	- 5.28 ± 5.5	- 7.61 ± 5.5
Agricultural peatlands	250	+ 6.63 ± 2.57	+ 6.12 ± 2.45
Peat extraction and stockpiles	63	+ 0.71 ± n.d	+ 0.69 ± n.d
Peat combustion	77.5 ± 7.3 PJ y^{-1}	+ 8.51 ± 8.97	+ 8.32 ± 0.71
Totals		**+ 18.97 ± 8.97**	**+ 8.06 ± 8.81**

Peatland fires: In many areas of the world natural fires ignited by lightning strikes were normal phenomena in peatlands. Today fire is most frequently the result of human activities. Peatland fires may lead to the ignition of the peat layers, especially after drainage. Such fires are difficult to extinguish and may last for many months despite extensive rains. The depth and extent of such fires depend on the oxygen availability, the moisture content, and the presence of cracks in the peat.

Emissions from biomass and peatland burning represent a large perturbation of global atmospheric chemistry. In the 1982-3 drought and fire in East Kalimantan, the area affected by fire included 5500 km^2 of peat-swamp forest. In 1997 and 1998 land clearance activities in Indonesia combined with an extended dry season created several months of forest and peatland fires. Two of the most intensive sources of smoke and particulate matter were fires on the peatlands of Kalimantan and Sumatra. Both the surface vegetation and the underlying peat were ignited. In Kalimantan some 7500 km^2 of peat-swamp forest was destroyed with a loss of surface peat of between 0.2 and 1.5 metres. Total emissions of carbon as a result of the fires are estimated to be equal to 10% of the global annual emissions from fossil fuel consumption.

Peatland inundation and re-wetting: Peatlands are inundated for rice cultivation, water reservoirs (especially for hydro-electricity), and mire restoration. Higher water table depths generally lower the carbon mineralisation rate. Nevertheless inundation and re-wetting do not necessarily result in lower emission rates.

Rice paddies are among the most important methane emitters in the world. Inundation of peatlands to create water reservoirs leads to significant emissions of both carbon dioxide and methane. Emissions from Canadian wetlands due to flooding are estimated to represent 5% of Canada's anthropogenic emissions.

The re-wetting of degraded peatlands would also be expected to lead to a decrease in carbon dioxide and nitrous oxide emissions. In practice, however, re-wetting of fen grasslands often leads to increased methane emissions, while carbon dioxide emissions may remain continuously high. This could be caused by the rapid decomposition of young plant material and is probably a transient phenomenon.

Water level fluctuations on such plots may cause a major increase in nitrous oxide emissions.

Re-wetting of drained alder forests leads to increased emissions of methane, but to decreasing nitrous oxide emissions.

Climate change: The distribution of mires and mire types over the globe clearly reflects their dependence on climate. As mires are concentrated in humid or cool regions, a changing climate can be expected to seriously affect their carbon balance and radiative forcing.

Most climate models suggest that the northern regions, which contain most of the world's peatlands, will become significantly warmer in the 21st century - continental areas (though this is less certain) becoming drier and oceanic areas becoming wetter. Since both net primary production and decomposition are closely related to moisture and temperature, significant alterations in the carbon dynamics of peatlands may result.

Some researchers stress the importance of alterations in the water table level, which might increase carbon accumulation in northern peatlands but might create a greater source of carbon dioxide in the more southern peatlands. Others stress the importance of a rise in temperatures and suggest that a net loss of carbon will take place in northern fens but a net gain in northern bogs.

The behaviour of permafrost peatlands will also be important, as both decomposition and net primary production are accelerated following permafrost melt. In general, methane emissions from peatland ecosystems will decrease with drying. Increased temperatures and thaw depth in wet tundra ecosystems could, however, also increase methane fluxes, especially when, as climate models indicate, precipitation at northern latitudes increases.

It may be concluded that there are still too many uncertainties in the magnitude and the direction of potential changes to arrive at a final conclusion on the reaction of mires and peatlands to global warming.

Conclusion: The atmosphere and the ocean, and the interactions they have with living things constitute a complex dynamic system with many interconnections and feedbacks. This complexity explains the uncertainty and controversy about greenhouse gases and climate change[183]. Most scientists believe that small changes in the "inputs" to the climate system will result in small changes to the resulting climate and that climate change will take place gradually over a period of many decades. If change is gradual, the overall economic impact on wealthy countries will probably be modest. Because of the feedbacks, the response of the climate to an increase in greenhouse gases could, however, also be "nonlinear" meaning that a small change in an input might produce a major change in climate, such as might be brought about by a sudden change in the general pattern of ocean circulation. If that happens, the economic costs to wealthy countries could be very large, as much new investment might be needed in a very short period of time.

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[183] http://www.gcrio.org/gwcc/toc.html

Whether it is fast or slow, climate change is likely to have greater economic impacts on poor countries than on rich countries, because poor countries have less capacity to adapt to changes and because traditional life styles depend more directly on a specific climate. In the long run, if sea levels continued to rise, even developed countries might begin to experience serious costs, as many of the world's largest cities are in low-lying coastal locations.

Because of this small but realistic risk of large and negative effects of climate change, a precautionary policy[184] should take into account the climate regulatory function of mires and peatlands, especially their role as major long-term stores of carbon.

(n) Regulation of regional and local climates

Mires have a specific microclimate, which often differs from that of their immediate surroundings. Their microclimate is characterised by a greater variation in temperature, higher air humidity, greater fog frequency and greater risk of night frosts compared with that of mineral soils. There are slight differences between the maximum temperatures and pronounced differences between the minimum temperatures of mires compared with surrounding mineral areas[185].

Peatlands are by nature wet landscapes and are usually situated in terrain depressions into which cooler and heavier air flows ("Kaltluftseen"). This stimulates fog and dew formation[186]. As a consequence, the soils of both pristine and reclaimed peatlands are significantly cooler in summer than mineral soils, and the air temperature is also lower. Forested tropical peatlands have lower mean and maximum temperatures than those that have been deforested[187].

Mires and peatlands strongly depend on the prevailing climate. On the other hand, they also influence the regional and local climate through evapotranspiration and associated alteration of heat and moisture conditions. This influence is larger in warmer or drier climates and smaller when the regional climate is colder or more humid. In areas with extensive peatlands the regional climate is consequently more humid and cool[188]. Drainage of mires in the boreal zone leads to a reduction in the minimum temperatures and a shortening of the yearly frost-free period, a process that is reversed by subsequent afforestation[189].

(o) Regulation of catchment hydrology

Traditionally, peatlands were generally seen as reservoirs or "sponges" storing water during wet periods and releasing it slowly during ensuing dry spells. In this way they were believed to reduce flooding following high precipitation and sustain water flow during times of low precipitation and consequently to have a "buffering" effect on

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[184] See also § 5.4 (11).
[185] Heathwaite 1993. See also § 3.4.1 (ea).
[186] Edom 2001b.
[187] Takahashi & Yonetani 1997.
[188] Edom 2001b.
[189] Yiyong & Zhaoli 1994, Solantie 1999.

catchment hydrology. This traditional view can, however, no longer be upheld unconditionally[190].

With respect to the hydrologic reservoir or water storage function of peatlands it is necessary to distinguish between a static and a dynamic storage component[191]. The static component is the water in the permanently water-saturated peat layers (the catotelm) and the water that is physically or chemically bound into the uppermost peat layers which are periodically exposed above the water level. Depending on their thickness and extent, peatlands may have a very large static water store as undrained peat consists of 85 - 95 % water. In general this water either does not move or moves only slowly and therefore scarcely participates in the annual water cycling and regional water regulation.

The dynamic storage component consists of the rapidly exchangeable water volumes in and over the uppermost peat and vegetation layers (the acrotelm), or, in drained peatlands, the uppermost soil. It is composed of (drainable) soil pore water, water cushions in and under the peat, water in peatland hollows and pools, and inundation water. These different fractions imply that different mire types may have completely different dynamic storage characteristics.

As peat accumulation requires high water levels at the mire surface during most of the year, the dynamic storage capacity of most mire types is limited. In times of abundant water supply the available storage is rapidly filled and the surplus water drains quickly. Peat-covered areas therefore generally show considerable surface runoff, directly consequent on precipitation, and little baseflow[192].

Only mire types of which the peat layer can shrink and swell with changing water supply (such as percolation mires and to a lesser extent schwingmoor mires - see § 2.3), or that combine a large storage coefficient with a limited hydraulic permeability (such as acrotelm mires and patterned surflace flow mires including aapa mires) have a “buffering” effect on catchment hydrology.

Other mire types, such as immersion, water rise, and flood mires and most types of surface flow mires, do not bring about similar effects. The fact that flood mires in river valleys may play an important role in flood mitigation[193], is not related to their peatland or wetland character but to the fact that they lie in or near the valley. Mineral wetlands or dry land with similar topography would function in exactly the same way.

After drainage the water movement and storage characteristics of peatlands change considerably. Generally they start to resemble drier mineral soils: peak discharge is strongly reduced because the peat layer is no longer completely saturated and the dynamic storage capacity is increased[194]. In other cases, open drainage – as associated with afforestation and agriculture - increases peak charge rates, because the increased storage capacity within the peat afforded by the lowering of the water table is of lesser

[190] See e.g. Goode et al. 1977 for a good review.
[191] Edom 2001b.
[192] Burt 1995, Edom 2001b.
[193] Cf. Mitsch & Gosselink 2000.
[194] Edom 2001b.

importance than the higher density of open channels in the drained areas[195]. Similar effects result from soil degradation in drained fens, which leads to decreased infiltration of rainwater in the peat body and increased surface run-off[196].

Mires also influence the hydrology of their surroundings because of their evapotranspiration characteristics. In fens (which are also fed by mineral soil water) evapotranspiration often exceeds precipitation, leading to a decrease in run-off[197].

Groundwater charge from peatlands, i.e. the quantity of water flowing downwards through the peat into the groundwater of the underlying bedrock, is generally small[198]. In the long run the accumulation of peat in the lower parts of the catchment may lead to a rise in the regional groundwater level[199]. The reverse may happen in the cases of peatland drainage and peat extraction.

(p) Regulation of catchment hydrochemistry[200]

Ecosystems are linked with their neighbouring systems and continuously exchange matter, energy and information. Ecosystems regulate the flow of an in-flowing substance through transformation, buffering or storage (accumulation) resulting in a change in chemical concentrations in the outflow[201].

Mires accumulate carbon, nitrogen, phosphorus and other nutrients when annual production exceeds annual aerobic and anaerobic microbial decay. First, the vegetation transforms inorganic substances, e.g. CO_2, NO_3 or NH_4, via biochemical processes into organic components (C-org; N-org). Then the dead plant material undergoes several deformation processes collectively called decomposition, decay or humification resulting in the formation of peat.

The decay of organic matter in mires is determined by many factors including oxygen concentrations in the acrotelm and catotelm, the temperature regime, the chemical composition of the plant material, and pH. An important factor for the rate of peat accumulation is how long litter stays in the acrotelm before the anoxic conditions (lack of oxygen) in the catotelm peat layer reach it. The relation between aerobic conditions in the acrotelm and anaerobic conditions in the catotelm is highly sensitive to changes in the hydrological conditions caused by climatic or human factors. Lowering of the water level increases the oxygen in the soil and fosters fast aerobic decay. Under these conditions, carbon and nutrients are not longer accumulating, but are released from the peat.

Mires and peatlands have diverse effects on the chemical composition of the water in a catchment depending on their position within the catchment, the wetland water balance, the water source, and the related biological, chemical and physical

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[195] Richardson & McCarthy 1994, Burt 1995.
[196] Edom 2001b.
[197] Edom 2001b.
[198] Edom 2001b.
[199] Kulczynski 1949.
[200] Based on information from Michael Trepel. Hydrochemistry is the chemistry of water.
[201] Mitsch & Gosselink 1993.

processes[202]. Mires receive water of different quality from different sources. Water pathways include rainwater, surface runoff, lower groundwater, deeper groundwater, or river water inflow due to over-flooding.

Bogs by definition derive their water only from precipitation. Bog mires act as sinks for carbon and nutrients by accumulating carbon, nitrogen and other nutrients in their peats. The water flowing out of bogs is characterised by low pH and high concentrations of humic substances and ammonia[203]. Bogs therefore act as local sources for carbon and nitrogen in a catchment. The concentrations of humic substances, nitrogen and phosphorus in the run-off water can rapidly increase after bog drainage depending on land use practice, e.g. fertilisation, chalking, agriculture, forestry.

Groundwater-fed fens like spring mires or percolation mires have a high potential for the transformation of inflowing substances transported with the groundwater. At the interface between mineral substrate and peat denitrification leads to a decrease in the nitrate concentration of the inflowing groundwater[204]. Additionally, the inflowing nutrients are partly stored through peat accumulation. Groundwater fed fens are able to improve the water quality in a catchment. Drainage and agricultural intensification both in the fen and in the catchment affect this functioning. Due to increased nutrient concentrations in the groundwater following fertiliser application in the catchment, the transformation potential can be over-used, resulting in an increased nutrient availability in the fen and decreased biodiversity. Drainage activities change the water pathways and therefore the mixing of different water sources. As a result, groundwater influence decreases and rainwater influence increase which affects the vegetation composition in the fen.

In flood mires and many terrestrialisation[205] mires, freshwater inflow is the main water source. These mire types foster processes which reduce chemical concentrations, such as denitrification, sedimentation or plant uptake. These wetlands act as sinks for nutrients in the catchment when the outflowing load has decreased compared to the inflowing load[206]. In the nitrogen cycle, denitrification is quantitatively the most important transformation pathway. The efficiency of such fen types in removing chemicals is related to the hydraulic retention time (the length of time the water is retained in the mire) and the inflowing water quality. High ammonia or N_{org} concentration will not be reduced significantly in small wetlands with low detention time. In some wetlands the inflowing nitrate, which is removed by denitrification, is replaced in the outflow by mobilised ammonia concentration. The net quantification of nitrogen and phosphorus retention in wetlands is therefore still a complex task. In addition to assessing the inflow and outflow concentrations of chemical substances it requires an experimental approach for the quantification of internal nutrient transformation rates[207].

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[202] Bedford, 1999.
[203] E.g. Heikkinen 1994.
[204] Blicher-Matthiesen & Hoffmann 1999, Haycock et al. 1993.
[205] I.e. immersion and schwingmoor mires, cf. § 2.3.
[206] E.g. Devito et al. 1993; Verhoeven & Meuleman 1999. See for a practical regional example Byström et al. 2000.
[207] Cf. Lamers 2001.

Mires and peatlands have diverse effects on the hydrochemistry of a catchment. Mires receive water of different quality from different sources, including rainwater, surface runoff, lower groundwater, deeper groundwater, or river water inflow due to over-flooding. Specific regulation functions of certain mire types include:

- Bog mires which derive their water only from precipitation act as sinks for carbon and nutrients by accumulating carbon, nitrogen and other nutrients in their peats. They therefore act as local sources for carbon and nitrogen in a catchment.
- Groundwater-fed fens have a high potential for the transformation of in-flowing substances transported with the groundwater. They are able to improve the water quality in a catchment.
- In flood mires and many terrestrialisation mires, freshwater inflow is the main water source. These mire types foster processes which reduce chemical concentrations such as denitrification, sedimentation or plant uptake. These wetlands act as sinks for nutrients in the catchment.

Because of these properties, peatlands have a capability for the advanced treatment of secondary municipal wastewaters. Results from several systems indicate reduction in B.O.D., suspended solids, nitrogen and to some extent phosphorus.

(q) Regulation of soil conditions

The peat blanket of mires protects the underlying soils from erosion. With respect to adjacent soils[208], undrained peatlands prevent concentrated/preferential water flow which would erode these soils. The insulation capacity of peat retains permafrost far outside the zone of continuous permafrost, e.g. in parts of China and Mongolia.

3.4.4 Informational functions

(r) Social-amenity and history functions

Social-amenity functions include attachment to place and interactions with other people. The attachment to place is “the most important and least-recognised need of the human soul”[209]. Human beings have always been in close contact with wetlands and peatlands. Ancestral hominids and early human beings appear to have lived at and around wetland sites. The 1.5-million-year-old Turkana Boy, the most complete skeleton ever found of *Homo erectus*, was excavated in what had been a lagoon near the edge of a lake or an oxbow of a river[210]. Bog bodies, tools, ornaments, weapons, and other archaeological remains found in abundance in peat testify to the long and intense relationship between people and mires[211].

This relationship was not unambiguous: peatlands were simultaneously seen as life-bringing and life-taking, as repelling and inviting, as “water and fire”[212]. In early 17th century England, fens were described as: “The air nebulous, grosse and full of rotten harres; the water putred and muddy, yea, full of loathsome vermine; the earth spuing,

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[208] Stewart & Lance 1983.
[209] Weil 1971
[210] Coles 1990, Leakey & Lewin 1992.
[211] Glob 1965, Moore 1987, Coles & Coles 1989, Müller-Wille 1999.
[212] Cf. Baaijens 1984, Blankers et al. 1988.

unfast and boggy..." But other voices of that time recognised their value in providing fodder for horses, cattle, and sheep, as store of "osier, reed and sedge", and as "nurseries and seminaries" of fish and fowl, from which thousands of people gained their livelihood[213].

Relatively few people lived or live entirely from and in wetlands and peatlands[214]. For many more people, peatlands were and are part of their home area: the community they share with other human beings, with plants and animals, and with familiar topography[215].

> Sometimes Johan Clemme would ponder whether he had done right in opening this wilderness for man. He loved the land because of its sadness and its poverty. He loved it because of the secrets of its soil, the sunken world of plants, trees, and animals. He loved the land because of its wide heaven. After them, all generations who lived there, he loved. He knew that among them were many who could only live in the bog and would be unhappy everywhere else. In their silent faces he recognised himself.
>
> Aar van der Werfhorst 1945

This notion of identity and continuity is expressed in many poems[216], novels[217], myths, fairy tales and fiction[218], songs[219], films[220], and other works of art[221], in a myriad of books and documentaries on local and regional peatland history[222], in language and expressions associated with peatlands[223], in names[224], in museums[225],

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[213] Wheeler 1896, Pursglove 1988.
[214] Examples include the former Fen Slodgers in the English Fenlands (Wheeler 1896), the Marsh Arabs (Ma'dan) of Southern Iraq (Thesinger 1964), and the Kolepom people in Irian Jaya (Serpenti 1977).
[215] An aspect often referred to in nature conservation as representativity.
[216] Poems inspired by peatlands, a.o. from Thomas Moore 1779-1852, Anette von Droste-Hülshoff 1797 - 1848, Nikolaus Lenau 1802 - 1850, Henry Wadsworth Longfellow 1807 – 1882, Edgar Allan Poe 1809 – 1849, E. Pauline Johnson (Tekahionwake) 1861 – 1913, Hermann Löns 1866 - 1914, Frans Babylon (1924 – 1968), Victor Westhoff (1916 – 2001), Irving Feldman (1928 -). See also Barlow 1893, Shane 1924, MacCormaic 1934, Cook 1939.
[217] Some examples include novels on daily life in peatlands (e.g. Brontë 1847, Crocket 1895, Maas 1909, Diers n.y., Coolen 1929, 1930, Carroll 1934, Laverty 1943, Van der Werfhorst 1945, Macken 1952, Selbach 1952, Ehrhart 1954, Kortooms 1951, 1959, Kortooms 1949 (after the bible the most sold book in the Netherlands!, de Werd 1984), Wohlgemuth 1962, Lepasaar 1997, Seppälä 1999, Vasander et al. 2000, books on the role of peatlands as refugia for fugitive slaves, as Nazi concentration camps, and as centres of anti-Nazi resistance (e.g. Beecher Stowe 1856, Langhoff 1935, Kortooms 1948, Melež 1972, Perk 1970), anthologies (Juhl 1981, Murphy 1987, Sýkora 1987, Ludd 1987, Blankers et al. 1988), peatland biographies (Smits 1987, Veen 1985, Aardema 1981, Van Dieken n.y.),
[218] E.g. Garve 1966, Kluytmans 1975, Stebich 1983, Schlender 1987, Talbot 1986, Conan-Doyle 1902,
[219] E.g. the classic anti-fascist 'Song of the Peatbog Soldiers' (Langhoff 1935), the modern German Rock group *Torfrock*, the Dutch pop group *Rowwen Hèze*.
[220] E.g. the Dutch television series "Het Bruine Goud" ("The Brown Gold"), Irish films "Eat the Peach" and "I went down".
[221] See footnote below under (ee) Recreation and aesthetic values.
[222] E.g. Van der Hoek 1984, Gerding 1995, Müller-Scheesel 1975, Gailey & Fenton 1970, Ahlrichs 1987.
[223] E.g. Crompvoets 1981.
[224] Of places (e.g. Veenendaal, Veendam, Ballynamona, Coolnamona), persons (Thomas Moore, John Muir, Otto Veen, Jean Marais, Gunnar Myrdal, Andres Kuresso), pop groups (the German *Torfrock*, the Chicago band *Peat Moss*), and even a country (*Fin*land / *Suo*mi).

and on stamps[226] and on banknotes[227]. The very remnants of mires and peatlands, anthropogenic peatland patterns, and continued traditional exploitation techniques and folklore are reminders of former socio-economic conditions[228], and reflect some of the *history functions* of mires and peatlands.

Their limited accessibility has often turned mires into political, cultural, and language borders[229].

As part of their *social amenity functions* peatlands may act as a bringing-together point for social contacts, places where people meet and acquire company, friendship, solidarity, and self-respect[230]. In some areas, these social aspects of employment ("keeping the rural area alive") have constituted decisive reasons for peat extraction, for example in the midlands of Ireland and central Finland.

Data on employment in peatland agriculture, peatland forestry, and mire conservation are not available on a global scale[231]. In direct industrial peat extraction (Tables 3/17 and 3/18), employment has been declining during the last decade, because of decreasing production volumes[232] and the introduction of more labour- efficient production techniques[233]. No data are available on indirect employment but a 1993 report[234] estimated the multiplier effect (the relationship between direct and combined direct/indirect employment) at between 1.15 and 1.25.

Table 3/17: Labour force in the global peat industry in man-years

	1990		1998		1999	
	Average	Peak	average	peak	Average	peak
Eastern Europe	89 900	91 200	25 900	26 400	25 600	26 400
Western Europe	8 100	11 000	8 400	15 200	8 300	13 800
North America	2 500	3 600	3 100	3 900	3 200	4 000
Total	100 500	105 800	37 400	44 800	37 120	44 500

(IPS questionnaire 2000, preliminary data, supplemented by estimates)

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225 E.g. the peatland museums and visitor centres in Galway (Ireland), Peatland World (N. Ireland), Vinkeveen and Bargercompascuum (Netherlands), Hautes Fagnes (Belgium), Oldenburg (Germany), Sooma (Estonia). "Pete Marsh" (Lindow Man) is the second most visited exhibit in the British Museum London (pers. comm. Richard Lindsay).

226 E.g. recent issues from Denmark, Estonia, Germany, and Ireland.

227 E.g. the Estonian EK25 note, the Canadian $5 note.

228 Cf. Sestroretskoje boloto near St. Petersburg where Lenin hid from the tsarist police; Joosten 1987, Moen 1990.

229 Cf. Hueck n.y., Weijnen 1947, 1987, Overbeck 1975**,** Crompvoets 1981. Cf. the border between Tomsk Oblast and Novosibirsk Oblast (W. Siberia) running through Vasyugan, the largest mire complex in the world.

230 Cf. Etzioni 1998, who stresses that group values, though "pleasant", are not *ipso facto* "good" and should be judged by external criteria.

231 Because most agricultural, silvicultural and conservation statistics do not differentiate between peatlands and other types of lands.

232 E.g. in the former Soviet Union, Cf. section 3.2.1 above.

233 Sopo & Aalto 1996.

234 Bord na Móna 1993.

Table 3/18: Peak labour force in various countries in man-years

	1990	1998	1999
Belarus	12 000	7 500	7 000
Russia	56 000	12 500	13 500
Ukraine	18 600	4 200	2 700
Estonia		300	1 200
Latvia	4 000	1 100	1 200
Lithuania			
Finland	3 000	4 400	3 400
Sweden	1 200	1 200	1 200
Poland	600	800	800
Germany	3 500	2 500	2 600
Ireland	3 900	3 800	3 300
United Kingdom	500	500	500
USA	1 200	900	900
Canada	2 400	3 000	3 100
Total	105 600	45 000	44 100

(IPS questionnaire 2000, preliminary data, supplemented by estimates)

(s) Recreation and aesthetic functions

Mires and peatlands have *recreation value* in that they provide opportunities for recreation. The limited accessibility of mires and peatlands ("too wet to drive, too dry to boat") does not make them particularly suited for mass recreation. Where facilities[235] are available, however, large numbers of people may visit these open, often softly undulating landscapes with their endless skies and mirror-like water surfaces, their wealth of extraordinary species, their historical dimension, and their treacherous, mysterious but exciting character[236] (Table 3/19). Many more mires are used for low-intensity recreation by amateur hunters, anglers, gatherers of berries and mushrooms, hikers, skiers, boaters, and by other people looking for wilderness, quietness, and remoteness.

[235] E.g. in peatland national parks with visitor centres, boardwalks, and/or specialised vessels.
[236] Masing 1997.

Table 3/19: Annual number (mostly in visitor days) of recreational visitors in selected mire/peatland nature reserves

Mire/peatland reserve	Number (* 1000)
Burns Bog (Canada)[237]	50
Everglades NP (USA)[238]	1 141
Kushiro Shitsugen NP (Japan)[239]	740
Exmoor NP (UK)[240]	220
Snowdonia NP (UK)[241]	6 600
North York Moors NP (United Kingdom)[242]	9 500
Peatlands Park (Northern Ireland)[243]	80
Connemara National Park (Ireland)	78
The Broads (United Kingdom)[244]	3 000
Groote Peel NP (Netherlands)[245]	165
Spreewald Biosphere Reserve (Germany)[246]	4 000
Hautes Fagnes (Belgium)[247]	350
Miscou Island (New Brunswick)[248]	6

Aesthetic functions attach to the appreciation of beauty. The awesome beauty of mires and peatlands has inspired artists since Albrecht Dürer[249]. The openness,

[237] Estimate furnished by Gerry Hood.
[238] http://www.nps.gov/ever/current/ever99.pdf.
[239] 1998 data. Based on information from Hiroe Nakagawara, Kushiro International Wetland Centre 2000.
[240] Based on information from Exmoor NP Tourist Authority 2000.
[241] 1994 data. Based on information from Liz Jenkins Snowdonia National Park 2000.
[242] 1998 data. Based on information from Jo Hearne North York Moors National Park 2000.
[243] Based on information from Michael Morgen Peatlands Park 2000.
[244] http://www.pantm.co.uk/reports/purbeck/CombinedChapters.pdf
[245] 2000 data. Based on information from Staatsbosbeheer Groote Peel.
[246] Based on information from Dana Kühne TVb Spreewald e.V. 2000.
[247] Based on information from Cecile Wastiaux.
[248] Based on information from Randy Milton and Gerry Hood.
[249] “Der Weiher” (1495) of Albrecht Dürer (1471 - 1528) is the first known painting of a natural mire. Other artists inspired by mires and peatlands include a.o. Jacobus Sibrandi Mancadan (1602-1680), Meindert Hobbema (1638-1709), Jan Luyken (1649 - 1712), Joseph Mallord, William Turner (1775 - 1851), John Crome (1768 - 1821), John Constable (1776-1837), Carl Blechen (1798-1840), Martin Johnson Heade (1819-1904), Frederic Edwin Church, (1826-1900), P.J.C. Gabriëls (1828-1903), Carl Krüger (1834-1880), Vasilij Polenov (1844-1927), Bernhard Willibald von Schulenberg (1847-1934), Victor Vasnetsov (1848-1926), Fiodor Vasil'ev (1850-1873), Elena Polenova (1850-1898), Vincent van Gogh (1853 – 1890, cf. Schmidt-Barrien 1996), Isaac Levitan (1860-1900), Gerhard Bakenhus (1860-1939), Richard tom Dieck (1862 – 1943), Alexej von Jawlensky (1864 – 1941),Valentin Serov (1865-1911); the Worpswede artists Carl Vinnen (1863 – 1922), Hans am Ende (1864 – 1918), Otto Modersohn (1865 - 1943), Fritz Mackensen (1866 - 1953), Fritz Overbeck (1869 – 1909, the father of the famous peatland scientist Fritz Overbeck, Overbeck 1975), Heinrich Vogeler (1872 - 1942), Paula Becker (1876 - 1907), Walter Bertelsmann (1877 – 1963), R. Stickelmann, H. Saebens, (cf. Weltge-Wortmann 1979, Busch et al. 1980, Riedel 1988); William Turner (1867 – 1936), William Hoetger (1874 - 1949), William Krause (1875-1925), Wilhelm Schieber, (1887-1974), John Bauer (1882 – 1917), Fryco Latk (1895-1980), Marius Bies (1894 – 1975), Sepp Mahler (1901 - 1975, cf. Konold 1998), Gerrit van Bakel (1943 - 1984, Bremer 1992), Mary Donnelly (x -), Jerry Marjoram (1936 -), Nikolaus Lang (1941), Anne Stahl, Hans van Hoek (1947 -), Etta Unland (1959, see also Stadtmuseum

patterns, and symmetry of many peatland landscapes are aesthetically fascinating[250], their blaze of colours varying from pastel and melancholic to deep green and bright red, and the delicate symmetry of specialised groups of micro-organisms[251]. Special conferences have recently been devoted to the aesthetics of mires and peatlands[252]. Some wild peatland organisms are specifically protected (and collected and marketed!) for their beauty, such as orchids and ornamental blackwater fish[253].

(t) Symbolisation, spirituality, and existence functions

Symbolisation, spirituality, and existence functions play an important role in the self-identification and group-identification of human beings. *Symbolisation functions* are those attaching to things which act as symbols of other values. Large conspicuous organisms, often mammals or birds[254], more seldom plants[255], and landscapes[256] may have such symbolisation value[257] for individuals, organisations and nations. Examples of the former are hunting trophies[258] (of peatland animals like moose (*Alces alces*), bear (*Ursus sp.*), grouse (*Lagopus lagopus scotticus*, *Lyrurus tetrix*), snipe (*Gallinago gallinago*), crocodiles (*Crocodilia*) and tiger (*Panthera tigris*). Some peatland organisms have a wider symbolisation value, including Eagles[259], Beavers[260], Crocodiles and Alligators[261], Cranes[262], Storks[263], and Herons[264], Pelicans[265], Larks[266], the Common Loon (*Gavia immer*)[267], and the Blue Iris (*Iris versicolor*)[268].

Oldenburg 1993, Janssen 1999); bogwood sculptors in Ireland including Michael Casey and the Celtic Roots studio.

[250] E.g. of excentric, concentric, and radiating bogs, aapa mires, palsas, and polygon mires, cf. Wright et al. 1992, Aaviksoo et al. 1997, Standen et al. 1999.

[251] E.g. Testacea amoebae, Desmidiaceae, Diatoms.

[252] e.g. Hakala 1999: "Suo on kaunis" (Mire is beautiful), Proceedings of 3rd International Conference on Environmental Aesthetics in Ilomantsi Finland 3-6 June 1998.

[253] Ng et al. 1994, Lee & Chai 1996.

[254] E.g. eagles as national symbols, that have triggered the founding of nature conservation movements in many countries (Masing 1997), the Giant Panda in nature conservation (WWF).

[255] E.g. the olive tree as a symbol of peace, the "flower of Scotland", the Maple Leaf.

[256] Mitchell 1994, Schama 1995.

[257] Cf. Lawrence 1993.

[258] Cartmill 1993.

[259] Masing 1997. All around the world, the eagle, the king of birds, is strongly associated with the sun, fire, air, life, sky, sun gods, and Resurrection. The eagle is believed to enjoy staring directly into the sun, which is equated with the ability of the pure in heart to see God and discern divine truths; Cf. http://ww2.netnitco.net/users/legend01/eagle.htm

[260] As a symbol of diligence, chastity, asceticism, and the willingness to sacrifice, cf. http://ww2.netnitco.net/users/legend01/beaver.htm. The Canadian Beaver (*Castor canadensis*) is the official symbol of the sovereignty of Canada, cf. http://www.users.fast.net/~shenning/beaver.html

[261] As a symbol of silence, deceit, and wisdom, cf. http://ww2.netnitco.net/users/legend01/crocodi.htm

[262] As symbols of happiness, justice, diligence, purity, loyalty, piety, filial gratitude, beauty, love, vigilance, contemplation, self-knowledge, wisdom, longevity, immortality, and Resurrection, but also as an evil omen, cf. http://ww2.netnitco.net/users/legend01/crane.htm. The Japanese Crane (*Grus japonensis*) is an important symbol of Japan (Iwakuma 1996).

[263] As fertility symbols and associated with springtime, birth, and good fortune. It was believed that the souls of unborn children lived in wetlands. Since storks frequented such areas, they were thought to fetch the babies' souls and deliver them to their parents. Because they are rumoured to feed their elderly parents, storks are a symbol of filial piety or gratitude. They are emblems of immortality and longevity.

[264] As symbols of contemplation, vigilance, divine or occult wisdom, and inner quietness.

[265] Exemplifying the sacrificial love of a parent for its offspring.

[266] As symbol of freedom, ardour, joy, youth, happiness, and the desire to be happy.

[267] E.g. in Minnesota and Canada (Cf. the Canadian $20 note).

[268] The national flower of Québec.

Spirituality functions involve an entity's role in religion and spirituality. In former times, mires were seen as mysterious and played an important role in religion and spirituality. This is illustrated by the sacrifices, which took place from the Neolithic age to the middle ages, that are found in peatlands[269]. Many of these were of precious goods or even of human beings.

Nowadays, *existence functions*, providing the notion of ecological and evolutionary connection, that we share this world with other entities with which we are related and for which we have a responsibility, are a considerable motive for nature conservation[270]. The "naturalness" of mires is a major source of interest, as mires often constitute the last terrestrial wildernesses, regionally and also globally[271]. The significance of such existence functions is illustrated by the widespread support for efforts to conserve species and ecosystems in other parts of the world, i.e. which most of those who support their preservation may never see in practice[272].

> "We need the tonic of wildness, - to wade sometimes in marshes where the bittern and the meadow-hen lurk, and hear the booming of the snipe; to smell the whispering sedge where only some wilder and more solitary fowl builds her nest, and the mink crawls with its belly close to the ground."
>
> Henry David Thoreau 1854

(u) Signalisation and cognition functions

The *cognition functions* of mires and peatlands are their functions in providing opportunities for the development of knowledge and understanding. One of the characteristic qualities of human beings is their curiosity[273] and the consequent pursuit of knowledge. Identifying, classifying and understanding patterns and processes in nature offers people a challenging and accessible means of developing intellectual capacities, including knowledge, computation, application, analysis, synthesis and evaluation[274]. Mires provide special, even unique, forms of information[275]. They constitute ecosystems with an incomplete cycling of material and a consequent

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[269] Cf. the extensive review in Müller-Wille 1999.

[270] Cf. Gorke 1999. In all cultures and major religions, there is a latent premise of the worth of life, indicating an underlying core of ethical values common to all people (Skolimowski 1990).

[271] Cf. Joosten 1999a. A related concept to "wilderness" is that of "integrity", which a.o. played a role in the resistance against large-scale peatland forestry in the Scottish Flow Country (cf. Stroud et al. 1987, Lindsay et al. 1988).

[272] Note the importance of the efforts of such international NGOs as the Worldwide Fund for Nature (WWF), the International Union for the Conservation of Nature (IUCN), Wetlands International (WI), and the International Mire Conservation Group (IMCG). Note also the efforts of many states, including those made in the framework of international conventions, especially the Wetland (Ramsar) Convention. An interesting example of frontier-crossing commitment is the Dutch Foundation for the Conservation of Irish Bogs.

[273] Illustrating the neotenous character of human beings, in which infantile characteristics are prolonged into maturity. Other characteristics of neoteny include the great size and long-continued growth of the brain, the tendency to play (cf. Huizinga 1938), spontaneity, openness to new impressions, and the capacity for widely extended sympathy (Midgley 1983).

[274] Kellert 1997.

[275] Information is strongly related to the concepts of difference and diversity (Joosten 1998). For a review on biodiversity values in peatlands, see Joosten 1996, 1999b.

continuous accumulation of organic material[276]. They record their own history and that of their wide surroundings in systematic layers, making them particularly suited to the reconstruction of long-term human and environmental history[277]. The data stored in the peat archives include macro-remains of peat-accumulating plants[278], pollen and spores of plants, including those from the wider surrounding areas[279] and all sorts of materials and substances that one way or another got into the mires. Some recent developments in peatland palaeoecology[280] include the detailed reconstruction of human life[281], of volcanic emissions[282], of the atmospheric deposition of heavy metals[283] and nitrogen[284], of atmospheric CO_2 concentrations[285], and of climatic change[286] and the associated role of solar forcing[287]. These recent developments illustrate that the significance of peatlands in this respect will increase in future[288].

Mires and peatlands are generally characterised by extreme conditions, which require special adaptations of the species which live there. These conditions include the scarcity of oxygen in the root layer, the presence of toxic substances, continuous cover by peat accumulation and rising water levels, the immobilisation and resulting scarcity of nutrients (especially in case of ombrogenous and calcareous mires), and the azonal climatic conditions[289].

Various mire types develop sophisticated self-regulation mechanisms over time[290] and acquire an exceptional resilience against climatic change[291]. This means that such mires are model examples of ecosystems whose long-term development can furthermore be studied with relative ease. Related features are the inherent tendency of mires to develop complex surface patterning[292] and ecosystem biodiversity[293] on various spatial and organisational levels (see Table 3/20). The extent to which

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[276] See § 2.2 in Chapter 2. Mires share this character with lakes, oceans, and corals, i.e. they are the only terrestrial accumulating ecosystems and, together with corals, the only long-term sedentarily accumulating ecosystems.

[277] For an overview of the palaeo-ecological values of peatlands and the importance of long-term studies: Overbeck 1975, Birks & Birks 1980, Godwin 1981, Frenzel 1983, Berglund 1986, Franklin 1989, Barber 1993, Joosten 1995.

[278] The first palaeoecologic reconstructions of vegetation and climate based on macro-remains in peat date back to de Chamisso 1824, Dau 1829 and Steenstrup 1842.

[279] Systematic pollen and spore analysis (palynology) of peats started with Von Post (1918). For a recent overview cf. Moore et al. 1991.

[280] The reconstruction of human and environmental past.

[281] Brothwell 1986, Coles & Coles 1989, Fansa 1993, Turner & Scaife 1995.

[282] Pilcher et al. 1995, Dwyer & Mitchell 1997.

[283] Cf. overview in Shotyk et al. 1997.

[284] Cf. Malmer et al. 1997.

[285] Wagner et al. 1996, 1999.

[286] E.g. Mauquoy & Barber 1999, Barber et al. 2000.

[287] By way of analysis of cosmogenic isotopes in peat, cf. Van Geel & Renssen 1998, Van Geel et al. 1998.

[288] By the development and application of new analytic techniques and knowledge a.o. in palaeo-physiology, organic and isotope geochemistry, palaeomorph-morphology (incl. phytoliths, fungal and moss spores, algal remains, sponge gemmoscleres, chrysophyte cysts, soot particles, rare pollen types, macrofossils), research in little-known geographical areas, and by an increased temporal and spatial resolution.

[289] Conditions not typical of the surrounding climate zone. Cf. § 2.7.

[290] Cf. Ivanov 1981, Joosten 1993.

[291] Couwenberg et al. 2000.

[292] Cf. various papers in Standen et al. 1999.

[293] Couwenberg 1998, Couwenberg & Joosten 1999.

biodiversity is influenced by mire size raises questions regarding the management and political level at which decisions on mires are taken: some types of biodiversity require (very) large areas[294].

Table 3/20: Mire biodiversity on various spatial and organisational levels[295].

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Mire organisational level	Name of that level*	Synonyms for that level as used in different literature references	Indication of size (m^2)[296]	Example
0 level	-	-	10^{-8}	Plant tissue, non tissue
1^{st} level	-	Elementary particle, Nanoform	10^{-2}	Single plant, moss clone, open water
2^{nd} level	Nanotope	Mire-microform, feature, element	$10^{-1} – 10^{1}$	Hummock, hollow, pool
3^{rd} level	Microtope	Mire-site, facies, element, segment, mikrolandšaft	$10^{4} – 10^{6}$	Hummock-hollow complex, pool
4^{th} level	Mesotope	Mire-complex, massif, synsite, unit, mesolandšaft	$10^{5} – 10^{7}$	Raised bog (as a whole)
5^{th} level	Macrotope	Mire-system, complex, coalescence, makrolandšaft	$10^{7} – 10^{9}$	Stormosse (Sjörs 1948); Red Lake Peatlands (Glaser 1992).
> 5^{th} level	Supertope	Mire-region, zone, district, province	> 10^{9}	Regional zoning of mires (Gams & Ruoff 1929, Ruuhijärvi 1960)

*proposed at the IMCG Workshop on Global Mire Classification, Greifswald, March 1998.

Signalisation functions include the function of acting as a signal or *indicator*[297]. As accumulating ecosystems, i.e. as “self-registering witnesses”, mires have an important signalisation value. The recent environmental impact of human activities can be assessed by comparing the information stored in recent peat deposits with that of deeper, older peat layers, where information on the pre-human situation is stored. As wildernesses that have been spared from direct human activities for a long time, mires may offer the necessary natural “zero” references that historical cultural archives cannot provide[298]. Ombrogenous mires have a particular value in this respect, since they depend solely on precipitation and are therefore well suited to studies of changes in

- atmospheric deposition (e.g. “acid rain”)
- climatic conditions,
- conditions in the cosmosphere (e.g. cosmic radiation, sun spot cycli).

Special adaptations of mire plants to acquire the necessary nutrients make these plants useful as environmental indicators, e.g. *Sphagnum* species as indicators of atmospheric pollution[299] or as indicators of geological resources[300].

[294] E.g. large mire patterns, large macrotopes, large predators, and migratory birds. See also Joosten 1999b.
[295] After Couwenberg & Joosten 1999.
[296] For lay readers it may be helpful to state by way of illustration that 10^{-2} = one hundredth, 10^{4} = 10,000, 10^{6} = one million.
[297] As, for example, in “economic indicators”.
[298] Joosten 1986, 1995, During & Joosten 1992.
[299] Wandtner 1981.
[300] Äikäs et al. 1994.

3.4.5 Transformation and option functions

Transformation functions concern the possibility of modifying and changing preferences, e.g. the development of new tastes, the improvement of social skills, and the growing awareness of existence functions[301]. These are important aspects of peatland educational programmes[302]. Outdoor experiences ("survival") in peatlands are increasingly used to develop social and management skills in civil servants, young criminals, and business executives[303].

Experience of wild species and pristine ecosystems is a major advantage in developing a consistent and rational world view, one that fully recognises the place of the human being in the universe as a complex organism whose existence depends upon other living beings and functioning ecosystems. Such experience may inform and challenge existing frames of reference: how to exist in a limited world, how to understand that world, and what value to place on it? It can promote the questioning and rejection of world views that lead to overly materialistic and consumerist preferences. Mires, as economical, stable and self-organising miniature-worlds that provide important historic references, may play an important role in this respect[304].

Option functions relate to the importance people place on a safe future, either within their own lifetime, or for future generations. The prospect of a safe future is a normal human need, and the perception that this prospect might be weakening has a negative effect on welfare. Option functions of mires include the future assurance of their production, carrier, regulation and informational functions, and of the benefits that still have to be discovered[305]. The ability of genetic and other biodiversity to evolve and to adapt to changing conditions is important, as it may provide future humanity with new genetic and ecosystem resources. The adaptations of peatland organisms to excess water and lack of nutrients are significant in this respect; they make possible relatively high productivity under extreme conditions and low intensity management[306]. The future archive function of peatlands is also of special importance: it is guaranteed by continued peat accumulation. Cultural archives only record what contemporary civilisation thinks will be important in future. Future generations will, however, require information from the perspective of that future, not from that of the time when the information is recorded: nobody records what does not change, and when a change has taken place it is difficult to reconstruct the former situation. This implies that required information often cannot be found in cultural archives and that one has to resort to natural archives[307]. Mires are therefore of

[301] Norton 1984, 1987.
[302] See § 5.4.2 (7) below. Cf. Irish Junior Certificate syllabus (see O'Cinnéide and MacNamara 1990, pp 195 – 199); and IPCC (Irish Peatland Conservation Council) programmes in Ireland.
[303] E.g. Kirsamer 2000.
[304] Joosten 1997, Couwenberg & Joosten 1999.
[305] Cf. the "serendipity value" of De Groot 1992. Cf. the recent discovery of the role of mires in the greenhouse effect, and the discovery of the filtration capacity of peatlands.
[306] Cf. Keddy 2000.
[307] A good example is the current greenhouse effect. Although the effect of greenhouse gases on world temperature has been supposed since Svante Arrhenius 1896, see special issue Ambio 26/1 (1997), continuous cultural records of CO_2 concentrations in the atmosphere only exist since 1953. For the reconstruction of greenhouse gas concentrations before that date, natural records in natural archives, e.g. peatlands (cf. Wagner et al. 1996, 1999), are required.

utmost importance as systematic, unbiased devices recording information on a changing society, one that our successors will want to look at from a different perspective to that of today[308].

3.4.6 The values of conservation and economics

This leads finally to the consideration of "conservation" and "economic" values, which most often feature in environmental conflicts[309]. These values are derivations from and combinations of various instrumental values, and, in the case of conservation, also of different approaches to intrinsic values. They are often expressed as complex concepts. Employment, for example, represents income[310] which makes it possible to fulfil various needs and wants. It also leads to a wide variety of social amenity benefits, which may be even more important. Similarly "conservation" involves a wide range of motives with respect to instrumental and intrinsic values, as becomes apparent when considering the motives for creating protected areas[311], e.g. for assigning Ramsar Listed Sites (Table 3/21). For a systematic analysis of Wise Uses of mires and peatlands it is necessary to be aware of these complex relationships. Table 3/22 gives an overview of the relationships between value types and conservation and economic values, and illustrates that the same value type may often operate in favour of both conservation and exploitation.

Table 3/21: Ramsar Listed Sites containing peat as at June 2000[312].

Ramsar Listed Sites	Number	% of sites with peat	Ha	% of Ramsar Sites Area
Total Ramsar Sites	1 028	--	78 195 293	100
Sites with peat	268	100	27 213 484	35
Sites with peat with recorded threats (peat extraction, drainage, mining, etc.)	118	29	7 883 161	10

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308 Joosten 1986.
309 See also Chapter 4.
310 Money as such has a signalisation function as an embodiment of human labour or of corn equivalents (classical economics) or as an indication of human gratification (neo-classical economics).
311 According to IUCN (1994), the main purposes of conservation management are: scientific research, wilderness protection, preservation of species and genetic diversity, maintenance of environmental services, protection of specific natural and cultural features, tourism and recreation, education, sustainable use of resources from natural ecosystems, and maintenance of cultural and traditional attributes. Various management categories are based on combinations of these objectives (cf. EUROPARC & IUCN 1999).
312 Based on information from Scott Frazier and Doug Taylor (Wetlands International).

Table 3/22: Relevance of focal points of "conservation" and "economic" motives of peatland land use with respect to various value types (D = diversity, patterns, N = naturalness, wilderness, processes, I = income, monetary profit, E = employment, social benefits).

Value types		"Conservation" motives			"Economic" motives		
			D	**N**		**I**	**E**
Anthropocentric instrumental = for the benefit of humanity	Production	Protection of genetic diversity of current production species	+		commercial exploitation of various resources	+	+
	Carrier	Securing space for natural processes and patterns	+	+	securing space for production and habitation and its commercial exploitation[313]	+	+
	Regulation	Protection of regulating capacities	+	+	use and commercial exploitation of regulating capacities	+	
	Social amenity	Protection of home area, "roots"	+		employment to guarantee company, friendship, and respect		+
	Recreation	Use for recreation, recuperation, stress mitigation	+		use and commercial exploitation of stress mitigation capacities	+	
	Aesthetics	Protection of beauty	+		use and commercial exploitation of this value or position[314]	+	
	Signalisation	Protection of general indicator function	+	+	use and commercial exploitation of indicators (e.g. monetary benefits)	+	
	Symbolisation	Protection of symbols	+		creation, use, and commercial exploitation of symbols	+	
	Spirituality	Protection of reflective and spiritual properties	+	+	use and commercial exploitation of this value or position	+	
	History	Conservation of cultural and natural "monuments"	+		use and commercial exploitation of this value or position	+	
	Existence	Conservation of processes, species, and ecosystems	+	+	use and commercial exploitation of this value or position	+	

[313] In this Table, and elsewhere in the document, the word "exploitation" is used in the sense of deriving benefit from, without any pejorative intent.
[314] E.g. in tourism or in advertisements for other commercial products, cf. De Groot 1992.

	Value types	**“Conservation motives”**			**“Economic motives”**		
			D	**N**		**I**	**E**
	Science	Conservation of sources of cognitive development	+	+	use and commercial exploitation of knowledge	+	
	Transformation	Securing the potential for transformation (education)	+	+	use and commercial exploitation of transformational properties	+	+
	Option	Protection of genetic diversity and evolutionary processes	+	+	protection and saving of non-renewable resources for future use	+	+
Intrinsic values	Noocentrism[315]	Protection of all rational beings and their environment[316]	+		use and commercial exploitation of this position	+	
Intrinsic values	Pathocentrism	Protection of all sentient beings and their environment	+		use and commercial exploitation of this position	+	
Intrinsic values	Biocentrism	Protection of all living beings and their environment	+		use and commercial exploitation of this position	+	
Intrinsic values	Ecocentrism / holistism	Protection of all beings and systems and their environment	+	+	use and commercial exploitation of this position	+	

(grey shading) Does not use/exploit the values as such, but only the people who value these values.

[315] Cf. § 3.1.
[316] “Their environment” means here: all relevant values (cf. the range of anthropocentric instrumental values) that are instrumental in the wellbeing of these beings.